

# The Antique Wireless Association Review

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# THE AWA REVIEW

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## Foreword

The most exciting news this year about the *AWA Review* is that it is now distributed free of charge to all AWA members. It becomes another of the benefits of membership, without raising the dues. The *AWA Review* is the AWA's peer reviewed historical journal. This change in *AWA Review* distribution is made possible by a generous donation from a long standing AWA member who wishes to remain anonymous. The result of this change is an approximately ten-fold increase in our distribution. This has the effect of exposing very many members to the content of the *AWA Review* who would normally not see it.

This year as in previous years, the *AWA Review* reminds us of the exceptional length to which our authors go in order to obtain historical material. Russ Kleinman, for one, went to Detroit to research the TECLA company and virtually moved in with the Clark family in the process. Bart Lee, in tracing the Dunwoody story, contacted U.S. Army General Ann Dunwoody, H.H.C. Dunwoody's great-great granddaughter, who connected him with others in the family. We are grateful to these and the other authors who applied exceptional efforts in researching their stories.

The current volume boasts a number of articles about passive detectors that were developed around the turn of the last century. These are the detectors of Hughes, Dunwoody, and Pickard, each described in separate articles. Eric Wenaas set out to write an article just on Pickard, but then took a much broader view and gave us a very detailed and informative comparative overview.

This promises to be another strong issue of the *AWA Review*, and best of all I don't have to urge you to buy one. You have all automatically gotten a copy, either at the Annual Conference if you attended, or afterwards by mail. A list of this year's *AWA Review* contents is:

• **Thomas E. Clark, Detroit's "Wireless Wizard"** by Russ Kleinman, Dick Clark and Karen Blisard. Kleinman and his team tell the story of Thomas E. Clark, a talented inventor who began working with electricity in the 1880's. His first experiments with wireless resulted from conversations with Nicola Tesla. He built a chain of shore stations around the Great Lakes and equipped ships with spark sets. In 1916 he formed the TECLA company to manufacture wireless equipment. This history draws heavily from company records and photos not previously published. TECLA is still in operation today, although they no longer produce radio equipment.

• **Mental Radio: Wireless and Telepathy** by Graeme Bartram. Bartram explores the history of beliefs about mental telepathy in the latter years of the 19th century, and then the use of broadcast radio as a means of testing those beliefs. Some of those holding the beliefs were very prominent in the development of radio itself. It is a fascinating story that has gotten little attention in the history of broadcast radio.

• **The Origins of the IEEE Edison Medal on its 100<sup>th</sup> Anniversary** by David and Julia Bart. This year marks the 100th anniversary of the Edison Medal of the IEEE. The Barts describe the origins of the medal, and various stories around its early winners. It is still the most prestigious medal given in the U.S. and Canada for achievements in electronics and electrical engineering.

• **Professor David Edward Hughes** by Ivor Hughes. Professor D.E. Hughes was a scientist who established a wireless link over a distance of 500 yards, and this around the year 1879! His work was not well publicized and he took a back seat to Marconi and others. He achieved fame and fortune through his telegraph inventions.

• **How Dunwoody's Chunk of 'Coal' Saved both de Forest and Marconi** by Bartholomew Lee. Lee describes the invention of the carborundum crystal detector, and its impact on the operations of the de Forest company in the U.S., and of the Marconi company in England and internationally.

• **From Coherers to Crystal Rectifiers** by Eric P. Wenaas. This article covers the development of radio detectors all the way from Hughes' 'microphonic joint' in 1879 to the 1N34A. This is a conspicuously scholarly effort, and lays out all of the precedence and disputes among the inventors.

• **The Development of Radio in a Small Southern City** by Allan Pellnat. This article recounts the origins of radio in Wilmington, NC, from its first marine wireless station in about 1912 until well into the broadcast era. The activities of local amateurs are also well documented. This a story of how the arrival of radio impacted life in a community.

• **The Gross Radio Company – A Historical Background** by Bruce J. Howes. Howes traces the development of the Gross Radio Company, a New York firm located on "Radio Row", specializing in good quality, low cost equipment for amateurs. The article gives us an itemized review of all of the Gross kits and assembled sets, from their origins in 1931 until their end in about 1941.

• **Meissner Regenerated** by Michael J. Murphy. In this article, Murphy describes regenerative circuits patented by Alexander Meissner using the Lieben valve in Germany. He argues that it is at least possible that Meissner 'got there first'.

Our sincere thanks are due to these authors for their fine and often painstaking efforts. We continue to use the services of experts in the field as peer reviewers. We believe that this process raises the overall quality of the *AWA Review*. The reviewers for this issue are:

Alan Douglas, William Fizette, Neil Friedman, Donna Halper, John Jenkins, Joe Knight, Robert Lozier, Crawford MacKeand, Hans Thomas Schmidt, Ludwell Sibley, Tom Perera.



We thank them for their insight and careful work. AWA members and others with an interest in wireless communication history are encouraged to submit manuscripts to the *AWA Review*. A section titled Tips for Authors follows. We try to make the publication effort more collaborative than challenging. The single most important message in this regard is to contact us early if you are considering writing an article.

A cumulative index of Tables of Contents of all previous issues of the *AWA Review* is maintained on the website of the AWA at <http://www.antiquewireless.org>. The index is found on the Museum page.

It is my distinct pleasure to bring you this volume of the *AWA Review*. I hope you enjoy it. If you have not seen the Review before, I hope it stimulates you to think of new ways in which you can contribute to this satisfying hobby. I look forward to receiving your manuscripts for next year's volume.

Robert P. (Bob) Murray, Ph.D.  
Editor  
Vancouver, BC, Canada



## Tips for Authors

The *AWA Review* welcomes any submitted article on aspects of wireless communications history. In general, shorter articles can be directed to the *AWA Journal* and longer manuscripts to the *AWA Review*. If you are in any doubt about where your article should best appear, please contact either or both editors.

The *AWA Review* will accept and publish Letters to the Editor as space permits. This will be a suitable way to submit your comments if you wish to take issue with a recent article published here, or make other brief comments on wireless history matters. Letters will not be peer reviewed, but will be edited, primarily for length at the discretion of the Editor. The Editor reserves the right to publish responses. Galleys of letters to be published will not be returned to the author. Text is limited to 400 words and no more than 10 references.

For first time authors, articles can be prepared with the help of a more experienced co-author, or the editor can help with the text in the editing process. Members with an interesting story to tell should not be discouraged by a lack of writing experience. The *AWA Review* will accept manuscripts in any clearly prepared writing style. A short style manual produced by the American Radio Relay League is available on request. *The Elements of Style* by William Strunk Jr. and E.B. White is available in most public libraries. Reference material should be cited within the text of the article in any of the accepted reference styles. Reference lists should include all of the sources mentioned in the text. Writers should look at the articles in this volume or in recent previous volumes for examples.

Articles submitted to the *AWA* will be laid out on the pages in a style made consistent within the entire publication. Therefore, please do not arrange your illustrations on each page but rather send the text in a file separately from the files for each illustration. This requirement applies equally to the *Journal* and the *Review*. (see, for example, "From the Editor" in the *AWA Journal*, April 2006, pages 4 & 5.) Text files can be prepared on any word processing software, but preferably on Microsoft Word. Illustrations are best sent as .JPG or .TIF files with a resolution of around 300 dpi. JPG files should be Standard (not Progressive) and Greyscale (not RGB). Files can be submitted as e-mail attachments directed to the editor.

Manuscripts submitted to the *AWA Review* will be peer reviewed. That is, they will be forwarded to one or more *AWA* member(s) with expertise in the area of the article. The reviewer's comments will be returned to the author(s) anonymously, so that the reviewer is comfortable with being candid in his or her response. After the reviewers' comments have been addressed by the author, the article will be type set in a publishing software (currently PageMaker), following which galleys will be returned to the author. This will be the last stage at which errors can be corrected. Normally only one set of galleys will be sent.

Articles submitted to the *AWA Review* should be developed in concept not later than early January of the publication year. A first draft should be submitted around March. The editor's deadline for submission of the completed volume to the printer is July 1, so that a final draft is expected around May 1. Articles not submitted on this schedule will be rescheduled for the next year's volume. For more information contact:

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## AWA Review

Thomas E. Clark, Detroit's  
"Wireless Wizard"©2009 Russ Kleinman, Dick  
Clark and Karen Blisard

## ABSTRACT

Thomas E. Clark was the inventor who brought wireless to the Great Lakes region. Inspired by Nikola Tesla while at the World's Columbian Exhibition in Chicago in 1893, Clark patented his own coherer design and a system of wireless telegraphy. At the peak of his success, Clark operated a network of almost 20 shore stations and many spark wireless telegraph stations on ships on the Great Lakes. Competition and lack of regulation eventually led Clark to withdraw his operating system from the Great Lakes. He incorporated as TECLA in 1916 and resumed the manufacture of wireless equipment. Clark was the consulting engineer for the broadcast station that became WWJ radio in Detroit after World War I. TECLA diversified into other product lines during the 1930's. Although the company no longer manufactures radio equipment, it remains successful today machining parts and making pet, marine and fishing tackle products.

Thomas E. Clark introduced wireless communication to the Great Lakes region. He was an innovator and visionary experimenter (Fig. 1.)

Clark's many inventions and patents include improvements in such diverse areas as display cabinet lighting, electric fans and heaters, humidifiers, looms, wireless telegraphy as well as voice transmission, electric cars, car and police radios, wireless railway train control, and automobile safety around railroad crossings. He was the first to equip steamships on the Great Lakes with wireless and he placed stations at strategic locations on shore to communicate with them. He was the consulting engineer when one of the first commercial broadcast stations came on the air.



Fig. 1. Thomas E. Clark about 1905. Photo Source: TECLA historical archive.

Clark counted many famous people among his friends, including James E. and William Scripps, Ty Cobb, Walter W. Massie, A. Frederick Collins, Nikola Tesla, Henry Ford, Charles Steinmetz, and Thomas Edison. He was as devoted to his family later in life as he was to his work earlier, but he never bragged about his great accomplishments. Although he

was a great storyteller who enjoyed sharing his experiences with his family and friends, he never sought the fame and fortune that he deserved and that other inventors of his time valued so highly. On April 17, 1909, one hundred years ago, the Sunday News of Port Huron, Michigan, called Thomas E. Clark an electrical genius and the "Wireless Wizard."



## HUMBLE BEGINNINGS

Thomas Edward Clark was born on May 10th, 1869, in the area of Tecumseh in Essex County in the province of Ontario, Canada.<sup>1</sup> Although it has grown to be a modern town now with upscale housing subdivisions and all the usual conveniences, Tecumseh, named after a prominent Indian leader, was mostly unincorporated forest and farmland at that time. In 1854, the Great Western Railroad intersected Tecumseh Road. This stimulated more rapid growth in the area as it became able to ship more grain and lumber. Initially known as Ryegate, Tecumseh incorporated as a town in 1921 with a population of 978.

Tom's mother was Mary Mero Clark, the daughter of a well-respected and influential French settler, pioneer and farmer in this French-Canadian area. Thomas E. Clark's father, also named Thomas, worked for the Grand Trunk Railway Company for 38 years as roadmaster of the Great Western division.

The young Thomas Clark went to grade school in Essex County. He did well enough at his studies to earn a scholarship commendation. His real interest was not in school but telegraph. His father was a railroad man, so Tom spent all his spare time at the Tecumseh and Belle River office of the Grand Trunk Railway.<sup>2</sup> Here he learned the Morse telegraph code and became familiar with the instruments used on the telegraph line that accompanied the railroad.

He learned about telegraph keys, sounders, relays, ground wires, and lightning arresters. He helped clean the old style crow's foot batteries with their zinc and copper electrodes. In a Detroit

News newspaper interview about 1907 he noted that "I got into trouble in the telegraph offices, because I was always taking the telegraph instruments and switchboards apart and disorganized the whole office. I shall not forget that day."<sup>3</sup>

When vacation time arrived, he would spend his time with the train dispatcher learning how to construct the telegraph instruments and the methods involved with dispatching the trains. These pursuits were not interrupted when the family moved just a few miles west to Detroit, Michigan, when Tom was eleven years old. He sold newspapers to make a little extra spending money and went to the old Woodmere Public School. By the time he was fifteen years old, Tom was working as the night operator at several points along the Grand Trunk Railway.

He had no formal schooling beyond this point. It is not likely that his family would have been able to afford to send him to a college such as Columbia, where professors such as Francis Crocker and Michael Pupin, who were at the cutting edge of technology, taught electrical theory to more affluent students such as Emil J. Simon around the turn of the century.<sup>4</sup>

## EARLY TECHNICAL TRAINING

In the autumn of 1884, Tom's enthusiasm impressed Mr. MacKay who was a train dispatcher. Mr. MacKay spoke to W.A. Jackson of the Detroit Electrical Works and told him that he knew of a boy with great potential and who wanted to work. Jackson, the head superintendent of the company, gave Tom a job

at the Detroit Electrical Works. This company made a wide variety of electrical products including telegraph instruments, medical induction coils, gas lighting devices, chandeliers, dynamos, motors, doorbells and buzzers. Tom wanted to learn all he could about the practical manufacture and use of these instruments. He also learned about test equipment such as galvanometers, voltmeters, ammeters, and the Wheatstone bridge.

In 1885 he went to Sault St. Marie, known as "the Soo," and worked with the managers of the Western Union Telegraph. He also helped manage the Bell Telephone Exchange there. He worked in this capacity for five years. It was also during this time that he assisted in the electrical installation of the Edison Electric Light Company at Sault St. Marie. He continued to learn and gained valuable experience, but had not yet found his niche.

In 1889, Clark returned to Detroit and took a job with the equipment department of the Detroit Light and Power Company. Then in 1892, at the age of 23 Tom got his next big chance and accepted the position of electrical engineer in the electric boat department of the Edison General Electrical Works at Schenectady, New York. He found this a great opportunity to learn more and the heads of various departments did all they could to help him. He offered to work for the department heads at night for no pay so that he could learn more about new developments and new equipment. He was a terrific note taker. The department heads appreciated the extra help, and Clark learned electrical theories and techniques that would be invaluable to him later. As a result of his employ-

ment with Edison General Electric, he attended the World's Columbian Exhibition in Chicago in 1893.

## AT THE WORLD'S COLUMBIAN EXHIBITION IN CHICAGO

It was the 400th anniversary of the landing of Christopher Columbus in the New World, and Chicago won the intense competition to host the great celebration. The preparations for the fair which occupied 630 acres took three years. The fairgrounds were opened to the public a year later than actually had been planned although the dedication ceremonies were held in October, 1892. Over 27 million people eventually passed through the gates during the six months of the Exhibition.<sup>5</sup> The International Exhibit of the fair was held in a building dominated by electrical inventions and exhibits. Thomas Edison, Western Electric, Westinghouse, and other many other commercial enterprises all had booths at the International Exhibit. Bids were accepted for powering the lighting for the building.

The bid submitted by Edison General Electric to power the exhibits with direct current at a cost of one million dollars was turned down in favor of Westinghouse and Nikola Tesla's alternating current system at half the cost. This decision caused Edison General Electric to retaliate by banning the use of Edison's light bulb at the exhibit. Inventors at the incandescent lamp department at Westinghouse designed an improved electric light bulb that sidestepped the Edison patents and allowed Westinghouse to introduce the public to the wonder of electric lighting produced by alternat-

ing current.

Into this grand event walked a short, thin, 25 year old Tom Clark looking quite uncomfortable in a coat, tie and dome-shaped bowler hat (Fig. 2). General Electric had picked him to be their electrical engineer in charge of the electric boat concession at the Exhibition. The boats, called "electric launches" at that time, were propelled by direct current motors and supplied by General Electric and Cornelius

Vanderbilt.<sup>6</sup> This was the largest collection of boats powered by storage batteries ever assembled up to that time. There were 60 low-slung boats that had cloth tops to screen the sun and that were each about 25 feet long.<sup>7</sup> The motors were noiseless and represented the peak of technology at the time. One boat could carry 36 visitors at a time navigating around the lagoons at the fair.

Clark earned his keep during a devastating fire at the fair by saving the electric boats from destruction. He ordered his men to dump the heavy batteries overboard so that they could save the boats. Afterwards the batteries were recovered and the boats restored to operation. Vanderbilt had feared that all the boats were lost, but Clark told him that all he needed afterwards was the money to pay the men he had hired to help him save the boats.

The most pivotal time of young Thomas E. Clark's life occurred at the Exhibition when he met Nikola Tesla. Clark's vision of a life of experimentation and

invention opened up as he listened to Tesla's daily lectures and demonstrations on the new science of high frequency and high potential oscillating currents. One of the talks that Clark heard Tesla give was about the propagation of electric waves into space using special equipment and a ground connection. Tesla also displayed gas containing lights, precursors to fluorescent lights of today, which were powered without wires by high frequency currents close to

them.<sup>8</sup> Tesla's dazzling public display included neon lights and many other electrical marvels. Clark had the opportunity to talk with Tesla personally many times to discuss how these feats were accomplished and what could be hoped for in the future. He and Tesla specifically discussed power transformers, inductances, capacitance, and oscillating currents.<sup>9</sup>

Clark met many other investigators who were from abroad



Fig. 2. Tom Clark at the 1893 World's Columbian Exhibition in Chicago. TECLA historical archive.

while at the fair, including Eugene Ducretet who had come to Chicago from France.<sup>10</sup> Ducretet knew Edouard Branly who had made the first coherer. He told Clark how Branly had used the coherer to detect static electricity in the atmosphere. The coherer, a glass tube with metal filings between plug-like contacts, was soon to be used as one of the first detectors in wireless radio. Clark, who could speak French, met Count Froloff who was on the staff of the Russian commission to the Exhibition and who also spoke French. Count Froloff told Clark of the experimental work of the



Russian scientist Popov, and how a tapper or common bell ringer could be used to decohere or reset Branly's coherer. Froloff and Clark attended many of Tesla's demonstrations and lectures together.

Clark also made the acquaintance of Mr. Church, who was connected with the *Electrical World* published in London and the *Electrical World and Engineer* which was published by McGraw Publishing in New York. Mr. Church helped Clark obtain copies of books about James Clerk Maxwell's treatise on electromagnetic wave propagation as well as translations of Heinrich Hertz's laboratory work and the experimental validation of Maxwell's theories.<sup>11</sup> Excited by all that he had learned, Tom Clark decided that he would pursue his own wireless experiments.

## AFTER THE WORLD'S COLUMBIAN EXHIBITION

During Clark's employment at General Electric he had the opportunity to meet with Elihu Thomson. Thomson was born in Manchester, England and he had moved to Philadelphia at a young age. Thomson was a prolific inventor who held over 700 patents. He introduced Clark to the electric arc lamp and the speaking arc that would be the basis of Clark's later experiments in wireless telephony, the transmission of voice rather than Morse code. Thomson had found that by shunting an arc lamp with capacitance and inductance and connecting up a microphone he was able to reproduce the human voice.

Clark also worked with Charles Steinmetz who was the head of the calculating department at General Electric in 1894.

Steinmetz had described the mathematics of alternating current and built the first power line circuit breaker.

While still employed by General Electric in 1894 Clark built a large electric power plant and several electric boats for the Tampa Bay Hotel in Florida. He also constructed General Electric's first charging stations on the Erie Canal for the electric boats that operated there. He built several electric lighting installations in large cities across the country from Massachusetts to Colorado.

In late 1894, around the time of his marriage to Agnes Jean Laing who was the daughter of a prominent man in the lumber business from Bay City, Michigan, Clark left General Electric and took the job of electrical engineer and superintendent of construction for the Buffalo Electric Company in Buffalo, NY. He was in charge of some of the largest electrical projects in Buffalo. This was another step up the ladder of success for Clark. Over the next few years he worked for a series of companies doing special engineering and patent work, including a great deal more work with electric boats and the charging installations for them. At no point though did he give up his interest in wireless experimentation.

## THE BEGINNING OF WIRELESS EXPERIMENTATION

After the close of the World's Columbian Exhibition in Chicago, Clark initiated his own studies in high frequency and high voltage apparatus based on his conversations with Tesla (Fig. 3) and he homebrewed his first coherer on a wooden block. The metal particles, which conducted electricity when they were exposed to a

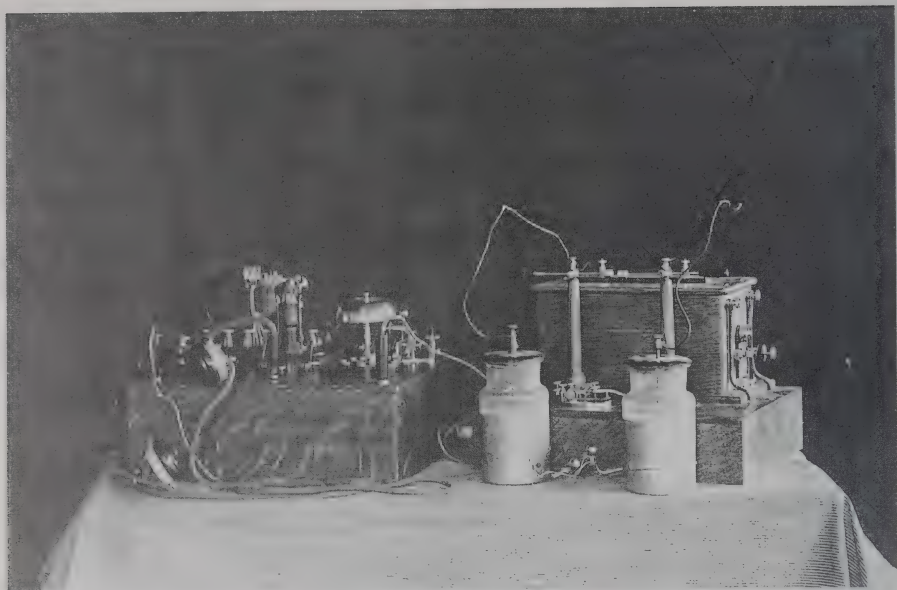


Fig. 3. Photograph of Clark experimental wireless set of 1896. Note the induction coil transmitter on the right with Leyden jar condensers in front. The receiver is on the left. Photo Source: TECLA historical archive.

wireless signal and thus could be used to receive wireless signals, were sifted through a fine wire screen in order to obtain a uniform size and then placed between the metal contact plugs of the glass coherer.

First he made the particles out of iron, but these oxidized and caused the coherer to function poorly. He then tried using just common nickel filings obtained with a special instrument so that he could get just a few small nickel particles. This seemed to work better because they did not oxidize and stop working. He made a coherer which was adjustable so that he could change the length of the gap between the contacts in which the metal filings rested. He also used a common bell tapper to decohere the filings, and a relay and tape register to record the incoming signal. Each dot or dash impulse of the Morse code was registered on the tape machine after passing through the coherer.

Clark also developed a spark coil, with its primary and secondary windings, and a vibrator for use with a dry battery with a small condenser across a spark gap. The initial antenna for his experimental set was one meter long.

He continued these experiments during his employment from 1894 to 1898 (Fig. 4). He developed these experimental wireless sets sufficiently that he was able to give the first demonstration of wireless telegraphy in New York City before the end of 1898 in a lecture to the Electrical Society there. At first, he himself did not believe that wireless telegraphy would ever be practical from a commercial point of view.<sup>12</sup> Several of his acquaintances felt he was wasting time or that he was a crackpot.

## **CLARK STARTS HIS FIRST BUSINESS— ELECTRICAL**

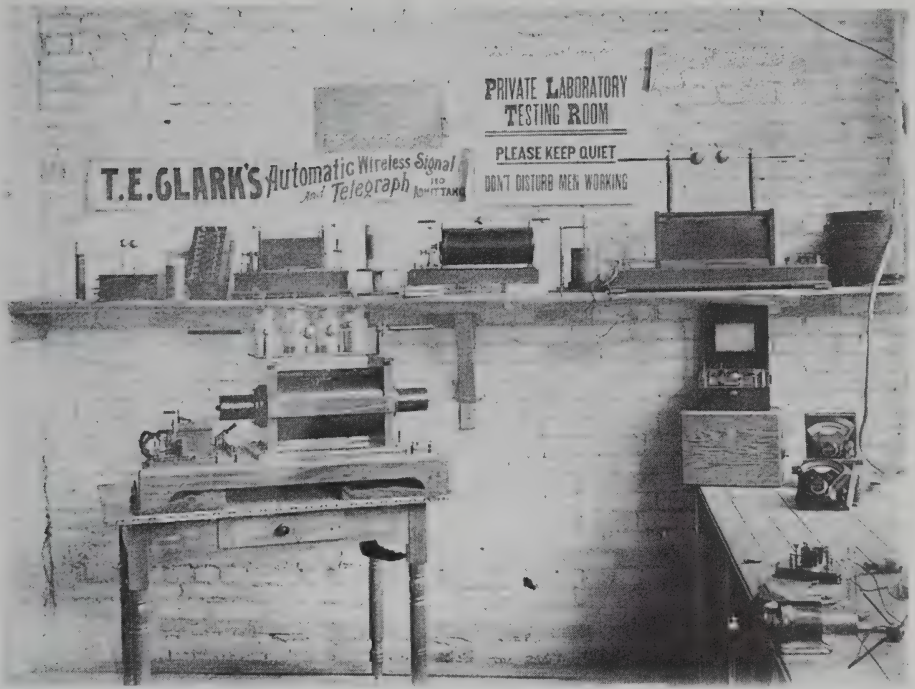


Fig. 4. Thomas E. Clark's laboratory in a photo from 1902. Several induction coil sets are visible. The signs on the wall read "T.E. Clark's Automatic Wireless Signal and Telegraph," "Private Laboratory Testing Room," and "Please Keep Quiet, Don't Disturb Men Working." Photo source: TECLA historical archive.

## SERVICE & APPLIANCE COMPANY

In December, 1898, Thomas E. Clark moved with his wife and one year old son James to Detroit where he set out in business for himself for the first time at 166 Randolph Street. He called this business the Electrical Service & Appliance Company. He manufactured various electrical devices, and continued his work in electrical engineering and contracting. He sold electrical supplies, working on a modest scale. He continued to pursue new ideas in areas besides wireless.

During late 1899 and the beginning of 1900, he designed and built an electrical automobile. (Fig. 5) It was all his own design and he manufactured the parts

himself. When friends asked if they could drive his electric car, he told them it would cost eight dollars. That is what it would cost him to hire a horse team to tow the car back from 8 Mile Road.<sup>13</sup> He could not interest any business investors enough to invest capital in his electric vehicle, but during 1901 and 1902 he operated a large automobile garage in Detroit and built charging stations for those electric vehicles that others were able to manufacture and sell. He constructed many plants for electric lighting in Detroit at this time, and installed telephone systems as well.

Clark also designed an ignition system for one of Henry Ford's prototype cars. The first spark coil Ford used was hand made in Clark's shop on Randolph





Fig. 5. Electric vehicle made by Thomas E. Clark who designed and built the propulsion system. It was powered by storage batteries. The initials "TEC" are written in script on the door. Photo Source: TECLA historical archive.

Street. Eventually Clark developed his own spark plug which he sold to Ford, Cadillac, Buick and other automobile manufacturers. Ford wanted Clark to be his chief engineer, but Clark refused saying "How would you feel working

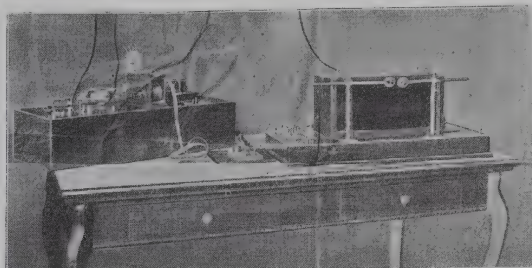
for someone else?"<sup>14</sup>

Clark also began the manufacture of wireless demonstration sets in 1898 that he sold to colleges and universities, as well as electrical supply houses. These were small, low power induction coil



Fig. 6. Demonstration set consisting of low power induction coil transmitter in the operator's hands and coherer receiver on the table made by Thomas E. Clark. The antenna is one meter long. From Clark Electrical Engineering Company bulletin of 1904. Photo source: TECLA historical archive.

# WIRELESS TELEGRAPH



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Fig. 7. Advertisement for wireless equipment placed by Thomas E. Clark Telegraph & Telephone Company in the November 22, 1902 issue of *The Electrical World and Engineer*.

sets with vibrators that were powered by dry cells and had a straight spark gap. (Fig. 6) The receivers had coherer detectors with tappers and relays. They were the first wireless sets commercially offered to the public in the United States. A couple of years later he advertised them in *Scientific American* and in *The Electrical World* (Fig. 7) and sold them to early amateurs and other experimenters. He sold over 200 of these sets in the first few years of the 20th century and over 1000 of them over the next 10 years.<sup>15</sup>

Clark said in a 1956 interview that many radio engineers and hams received their early training and inspiration while operating Clark wireless demonstration sets, including Alfred Goldsmith, who later became a Vice President and the General Manager of RCA. Donald McNichol obtained one of these sets including a coherer made by Clark.

McNichol became Superintendent of Telegraph for the Great Northern Railroad, head of the Postal Telegraph in New York City, and President of the Institute of Radio Engineers.<sup>16</sup>

Clark filed for a patent in 1900 for a shield and reflector for display lighting. Until this time, regular lights were strung in showcases. In Clark's lighting, all of the apparatus was hidden from view and the reflector directed light into the cabinet. At first, components of the apparatus had to be built all from scratch, including a way to anchor the filament of the light. The metal bending machine was of his own design. Clark built the first specially lit display by hand and then placed a male dummy dressed in a suit inside of it, calling this his silent salesman. He advertised the showcase by saying, "You've seen everything in the case, but you didn't see the lights." This inven-



tion was of practical use to retail businessés and he was able to sell them at a profit. The patent was eventually granted in 1901.

Clark used the extra money from the sales of the display cases to finance further expansion of his research into wireless telegraph and telephone. He needed more space with room for larger antennas and found what he needed at the old Banner Laundry building on Michigan Avenue across from the old Cadillac Hotel in Detroit. This location was also the closest place to the waterfront that he could rent that was suitable for his wireless apparatus. The rent was cheap, an important factor since he had little extra money at the time. He set up his experimental shop and machinery here, and then erected an antenna and mast on the top of the building. (Fig. 8)

He was able to secure space for another antenna and mast at the top of the Board of Commerce Building at the corner of Griswold and State Streets in Detroit. This location was two city blocks from the Banner Laundry site. He did not have to pay rent for the station at the Board of Commerce Building as all of his transmitting and receiving equipment was housed in the elevator penthouse. The management of the Board of Commerce building understood the developmental nature of his work and therefore allowed him to pursue his experiments there without charge.

### CLARK'S WIRELESS NETWORK EXPANDS

Thomas E. Clark seemed to be formulating a plan. If he could get enough wireless stations assembled on land, then he would be able to communicate with similarly equipped ships on the Great Lakes. He could monitor

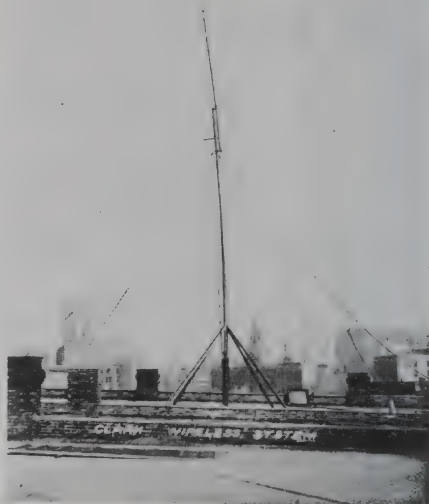
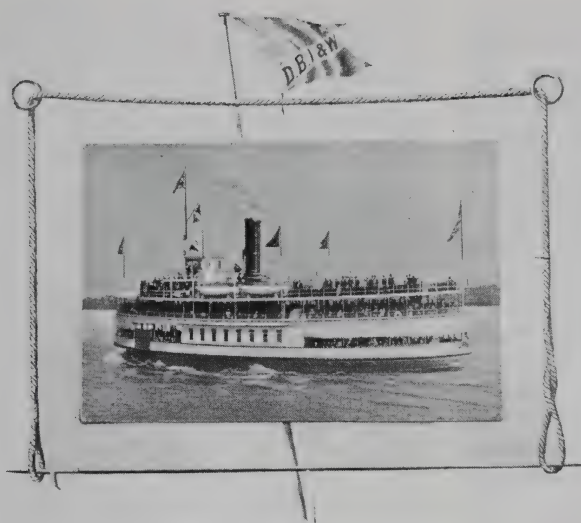


Fig. 8. Clark's Mast on the Banner Laundry Building in Detroit. Photo source: Detroit Historical Museum Collection.

their movements, send messages from passengers to family members or business associates on land, and provide emergency communications to those vessels that experienced mechanical difficulties or accidents while underway.

It is likely that he already had this intention when he contacted Walter Campbell of the Detroit-Belle Isle-Windsor Ferry Company. He demonstrated the function of the wireless apparatus with a miniature set he had hand-made. Campbell was impressed by the young man and the potential of wireless communication on the Great Lakes. He provided Clark space on the Belle Isle Pavilion Building on Woodward Avenue in Detroit. A small booth was erected on the dock complete with wireless instruments and an antenna.

Even more importantly, Campbell allowed Clark to install



DETROIT, BELLE ISLE &amp; WINDSOR FERRY CO'S

## STEAMER PROMISE

Fig. 9. The steamer *Promise* of the Detroit-Belle Isle-Windsor Ferry Company was the first vessel on the Great Lakes to communicate to shore by means of Wireless Telegraph. Thomas. E. Clark's Wireless Telegraph & Telephone Company's equipment was used for these tests. Photo source: TECLA historical archive.

his wireless apparatus on the ferryboats *Promise*, *Sappho*, and *Garland*. These were the first vessels in the Great Lakes area to be outfitted with wireless equipment. (Fig. 9) While carrying out communications with the ferryboats, Clark learned that they could avoid interfering with one another by operating on different wavelengths. Several land and ship stations could thus operate simultaneously.<sup>17</sup>

In this manner, about 1900, Clark had assembled a small but effective group of experimental stations and staff with which to gain information about signal strength, propagation and interference. He had three transmitting stations on land— on the Banner Laundry building, at the Board of Commerce, and on the Belle Isle Dock Pavilion. He also had put together stations on three

boats. All these stations worked together to try to find solutions for decreasing interference. They found that on some days signals were strong, and on other days they were weak or could not be heard at all. The atmosphere caused fading and noise. After the development of electrolytic and crystal detectors, Clark used these to better reception.

These stations were only used for development of the necessary practical experience to operate successfully and no commercial messages were sent by

them. Progress seemed slow at times and good results were frequently difficult to achieve. Clark found himself the object of frequent ridicule. Many people did not yet believe that dots and dashes could be sent without wires, and he was called “a nut” by some, “Wireless Clark” by others.<sup>18</sup> His own banker, Morris L. Williams, called Clark in to tell him that, “I knew your father, a railroad man. I can't understand a bright young man like you lending yourself to a fake like this when you know it can't be done.”<sup>19</sup> Bankers did not lend money for this kind of folly.

However, Clark was very encouraged by the progress he was making at this time. The Banner Laundry wireless station had a range of about eight miles. He found that coherer sets on the ferryboats were able to receive the



electromagnetic waves sent out from the dock. He then received permission to install testing equipment in the Mullen Coal Dock Building located across the Detroit River in Windsor, Ontario, Canada. He set up his transmitting and receiving equipment in a small space in the office of the building for the purpose of experimentation.

He also later set up an experimental station on Fighting Island (Fig. 10) in the Detroit River off of Wyandotte, Michigan. The Fighting Island station had a 225 foot mast for the antenna and was relatively free of the interference that had caused Clark trouble in downtown Detroit. Clark found that he needed more equipment and staff to continue expanding this work.

He was taking a chance, since he had not yet made a dime

of profit on wireless other than selling small sets to schools and experimenters. Nevertheless, when the Bell Telephone Company bought out the Independent Home Phone Company<sup>20</sup> in Detroit, he bought the jigs, dies, tools, and some of the remaining machinery and tools from the O'Connor brothers. He luckily was not required to pay cash, but was able to secure favorable payment terms that he could meet.

Equally as important, he was able to hire the experienced Independent Home Phone Company staff who were out of a job, among whom were some of the fastest wire telegraph operators in the world at the time. Also, the O'Connor brothers gave him the names of other independent telephone companies that needed a source for their electrical supplies. This brought more business and revenue.



Fig. 10. Interior of Fighting Island Clark wireless station, equipped with "Class A" transmitting transformer. A notation on the photo indicates that the operator is John Z. Hayes, Chief Postal Tel Co. and that the photo was taken in 1902. Photo source: TECLA historical archive.

## HELP COMES FROM UNEXPECTED BENEFACTORS

Clark at this time lived just a few blocks away from James E. Scripps, founder of the Detroit News. As Clark walked home from work, he would sometimes stop and talk with Mr. Scripps and his 19 year old son William. Tom had helped Will Scripps build a wire telegraph circuit between his house and those of his friends. A friendship developed between the kindred spirits, so Clark invited Mr. Scripps and his son to a private demonstration of his wireless equipment at the Banner Laundry building.

Mr. Scripps had heard of wireless telegraph, but he had never seen it in action. Clark activated his setup which had been assembled on tables in the loft of the building and he sent sparks flying as he sent a message on the telegraph key. A few moments later, a reply returned from the Board of Commerce building station. There was a heavy dark curtain at one end of the room, and Will was suspicious that he was being tricked. He told Tom he wanted to look behind the curtain, but when he did so he found to his amazement that there were no instruments nor any person there.

The impressive demonstration was a complete success. Mr. Scripps immediately grasped the possibilities of this new technology and wrote out a check to Clark in the amount of \$1000 in order to continue his wireless experiments. That was a lot of money in 1901.<sup>21</sup>

Clark also demonstrated his wireless apparatus in 1901 for the Mayor of Detroit, W.C. Maybury. Maybury noted that his message was correct as received, and wrote, "Here Edison received his first inspirations and now may we hope that a compeer if not a greater

than Marconi may have arisen in the favored territory!"<sup>22</sup>

Clark himself never mentioned meeting Marconi or discussing the development of wireless with him. In fact, Clark held Marconi a bit in contempt for being rather too commercially oriented and he privately blamed Marconi operatives later for some of the sabotage suffered by the Clark system. He felt that when Marconi sold stock, most of the proceeds went to England and British Marconi rather than for the further development of wireless in the United States.

Clark obliquely downplayed Marconi's achievements about 1907 in a prospectus when he wrote, "Where the old-world demonstrators have been successful in the comparatively easy work over the ocean, this company has been doubly successful in the extremely difficult problem of wireless transmission over land and fresh water."

## CLARK'S COMMERCIAL PRODUCTION EXPANDS

Clark was devoting an increasing amount of time and energy to the further development of his wireless equipment during 1902. He filed for a patent for his System of Wireless Telegraphy on February 17, 1902.<sup>23</sup> This patent broadly defined the work he had done to this point, and included an induction coil transmitter with an aerial and an adjustable spark gap and an automatic signal sending device with movable pins on a wheel turned by gears. (Fig. 11)

He also described further improvements in the receiving apparatus. Patent No. 805,412 for his System of Wireless Telegraphy was granted November 21, 1905. Also in 1902, Clark filed an application with the United States



BEST AVAILABLE COPY

No. 805,412. PATENTED NOV. 21, 1905.

T. E. CLARK.  
SYSTEM FOR WIRELESS TELEGRAPHY.  
APPLICATION FILED FEB. 17, 1902.

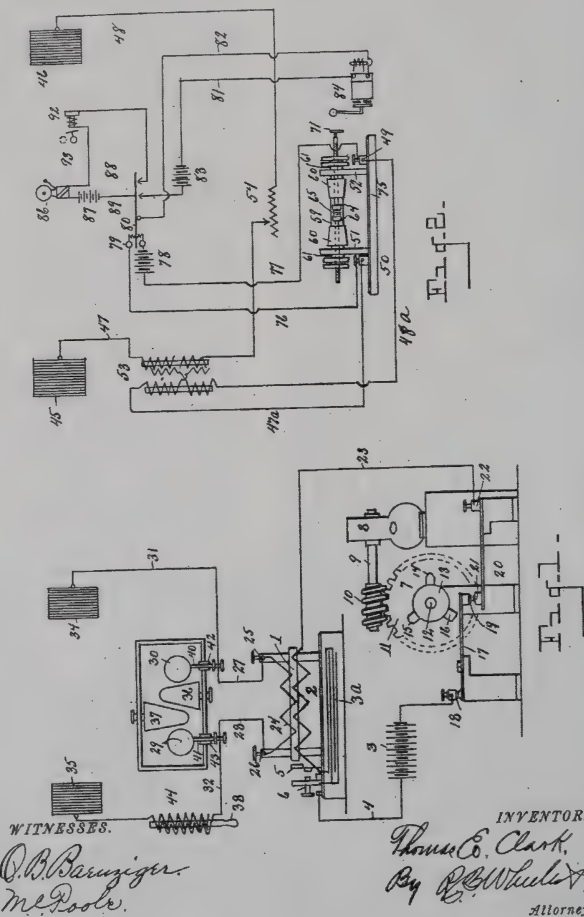


Fig. 11. Thomas E. Clark United States Patent No. 805,412 filed Feb. 17, 1902 for a System of Wireless Telegraphy. Photo source: United States Patent office website (uspto.gov.)

Patent Office for further improvements to the coherer, including the ability to adjust the gap and special coherer holding clips to make coherers rapidly interchangeable in case the one in use began to function poorly. The patent, No. 741,767, was granted

on October 20, 1903. Clark invented a wireless Fire Alarm Signal Box about 1902 as well.

After Clark filed his wireless patent applications, he rapidly expanded his production capabilities. He was manufacturing the smaller induction coil sets that

ran on dry batteries for retail sales as well as smaller numbers of larger, higher power transformer sets (Figs. 12 and 13) that were powered by alternating current. Prior to the advent of wireless, such coils were mainly used in X-ray devices and for experimentation in classrooms. Clark felt that these coils were not suitable for high frequency wireless work.

Clark corresponded extensively with the supply house Foote, Pierson & Company of New York to develop commercial production of the induction coils to his specifications.<sup>24</sup> Many of his early wireless sets were seen in advertising cuts with the Foote, Pierson & Company Twentieth Century pump handle telegraph key at the operating position. They gave Clark a 40% discount off list price for purchases of printing registers.

Foote, Pierson & Company had received specifications and

proposals from the United States War Department regarding furnishing and installing wireless equipment for Alaska and they were eager to contract in return with Clark for the manufacture by him of some of the necessary equipment such as coherers and decoherers. Clark wireless equipment was installed in Alaska for the United States government for the course between Nome and St. Michael in 1903.<sup>25</sup>

Foote, Pierson & Co. was concerned about whether Clark's apparatus was free of patent infringement issues. Lawsuits over patent issues became common and would eventually plague others who pursued the wireless dream in the next few years. Clark's early patents kept him clear of these types of problems, however, and he was never successfully sued over patent in-

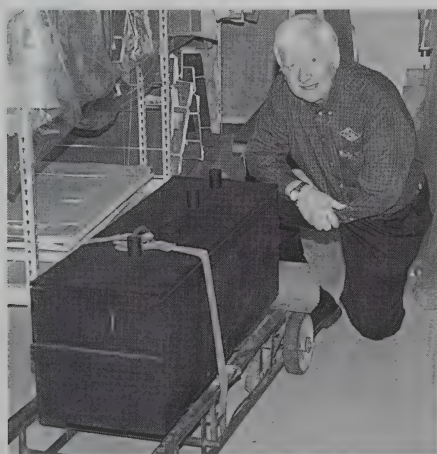


Fig. 12. Dick Clark, grandson of Thomas E. Clark, kneeling next to a large spark coil made by his grandfather in 1899 and currently in the Detroit Historical Museum collection. The electrical connections can be seen on the top of the wooden box. The coil is so heavy that it must be moved on a dolly. Photo source: Russ Kleinman.



Fig. 13. Very heavy four legged iron transformer dated 1899. Developed by Clark for use by experimenters and with ship transmitters. The plate on top reads "Clark-Wireless Instruments, Detroit, Mich." This instrument is in the Detroit Historical Museum collection. Photo source: Dick Clark.

fringement.

Clark similarly worked with the C.F. Splitdorf Company, also located in New York, to develop coils suitable for his wireless apparatus.<sup>26</sup> Splitdorf was already by 1902 building transformers for medical apparatus and high intensity coils for X-rays and wireless telegraphy. The Manhattan Electrical Supply Co. furnished coils also for Clark, but they did not function properly.<sup>27</sup> Some of the heavier induction coils were supplied to Clark by Queen & Co., Inc. of Philadelphia.<sup>28</sup> Clark contracted with J.H. Bunnell & Co. of New York for the manufacture of coherers for his wireless sets, although Bunnell may never have successfully completed any of them.<sup>29</sup>

As the Electric Service &

Appliance Company, Clark corresponded with the United Fruit Company in 1902.<sup>30</sup> He offered to equip their boat stations with telegraph equipment for \$1500 for each boat station and \$2000 for a land station that would then communicate with the head office. Aside from this, there is no other evidence of communication between the companies so it is unlikely that Clark got the contract. Within a few years time, United Fruit Company would install equipment made by the Wireless Specialty Apparatus Company which incorporated in 1907<sup>31</sup>.

## THE THOMAS E. CLARK WIRELESS TELEGRAPH- TELEPHONE COMPANY

Clark closed the Electric Ser-

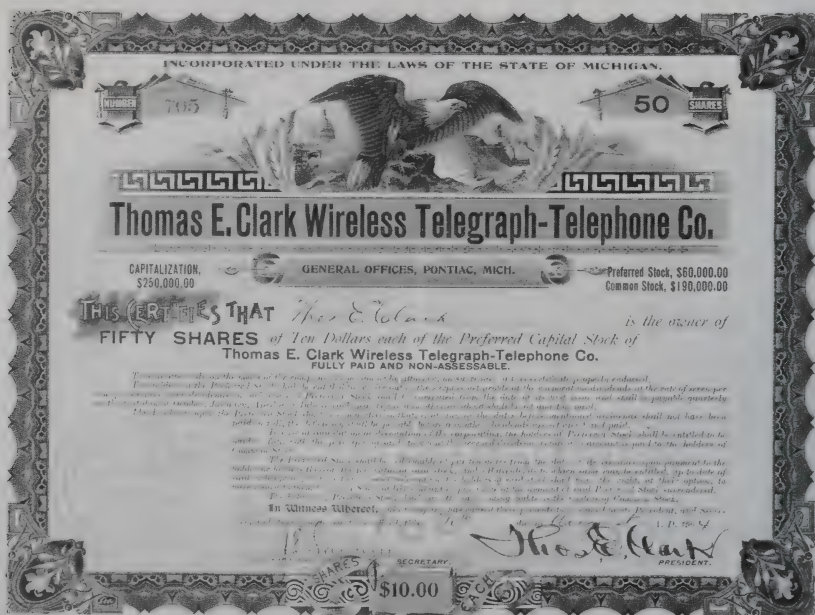


Fig. 14. Stock certificate of the Thomas E. Clark Wireless Telegraph-Telephone Company. This certificate is owned by Thos. E. Clark, and is signed by Thos. E. Clark, President. The date on it is August 10, 1904. Similar stock certificates were issued for the other Clark companies. Photo source: TECLA historical archive.



vice and Appliance Company in 1903 and incorporated as the Clark Electrical Engineering Company for the manufacture of electric specialties. He also incorporated the Thomas E. Clark Wireless Telegraph-Telephone Company (Fig. 14) at this time with general offices in Pontiac, Michigan. In July of 1903, Clark had the only display of wireless equipment at the National Electrical Contractor's Association convention held in Detroit.

His display was a favorite attraction, and it was always surrounded by a crowd. He demonstrated short distance wireless communication with a small antenna and mast at his booth. He allowed spectators to manipulate the transmitter, and he made sure that he always had another station ready to answer. Of course, he had his entire line of fully guaranteed wireless equipment on display at the booth.

He placed a large sign over the booth that read, "Thos. E. Clark Wireless Telegraph-Telephone Co., Manfrs. Of Wireless Telegraph Instruments, Offices in Pontiac, Mich." The display case was well lighted, of course, but the location of the lights was hidden to view. The narrower top shelf showed his smaller components. The largest shelf of the display cabinet contained fully finished, professional appearing wireless equipment.

He had two induction coil sets on display, and a coherer receiver set complete with bell and relay. All the wiring was underneath a mounting board. The portable induction sets and receiving units were tastefully displayed with the tops of their wooden cases opened.

In September, 1903, the Thomas E. Clark Wireless Tele-

graph-Telephone Company displayed equipment at the Michigan State Fair, held in Pontiac. Clark had two stations on the fairgrounds and sent and received messages from private parties as well as for officials of the fair.

In 1903, now with a factory located on the northwest corner of Cass and State Streets in downtown Detroit. (Fig. 15) Clark received an order from the government of Japan for wireless apparatus. These sets would be used in the Japanese artillery and Navy. Several years later in 1910, the Japanese would again approach Clark for improved wireless apparatus.<sup>32 33</sup> Clark also used this factory to conduct work on automatic wireless signaling of railroad locomotives. The factory



Factory, Laboratory and Testing Station  
North Cor. Cass and State Sts. Detroit, Mich., U. S. A.

Fig. 15. Thomas E. Clark Electrical Engineering Company factory at Cass & State Streets, downtown Detroit, about 1904. There were offices on the first floor, and the factory was on the top two floors. Photo source: undated company brochure, TECLA historical archive.

was a three story brick and stone building. Clark occupied the two upper floors with his manufacturing facilities. All manner of manufacturing equipment including lathes, drill presses, screw machines, planers, and winding machines could be found here. Motors supplied power to these machines through many unprotected belts hung from shafts in the ceiling.

There were separate laboratory areas for testing and for woodworking machinery to make cabinetry. A "force" of men was employed in the assembling of the instruments.<sup>34</sup> A portion of the top floor was used on occasion to teach students how to operate the wireless equipment after Clark's equipment was in more widespread use. The factory was not far from Clark's home on Avery Avenue<sup>35</sup> where he lived around the corner from Ty Cobb who eventually became a member of the baseball Hall of Fame.

## CLARK WIRELESS SETS ON STEAMSHIPS

Around 1902 or 1903, for the purpose of quickly developing extensive services for the Great Lakes, Clark arranged for a series of interviews with A.A. "Gus" Schantz of the Detroit & Cleveland Navigation Company. Schantz was the general superintendent and the passenger agent for this company. After telling Schantz about his equipment, Clark was told to get out of his office. Schantz said that it was all just a fake and he would talk no further with Clark. Nevertheless, Clark went back a second time. He was told the same thing by Schantz. On his third visit with Schantz, he was told that if he ever came back again he would be thrown out by the watchman.<sup>36</sup>

Clark was persistent however and learned that Senator James McMillen was an officer of the Detroit & Cleveland Navigation Company. Clark knew some of Senator McMillen's acquaintances, including McMillen's secretary George Black. Clark assembled a group of McMillen's friends including Black and made an appointment to see Senator McMillen. As a result of this meeting, Clark received permission to place his transmitting and receiving equipment on the steamer *City of Detroit* running between Detroit and Cleveland on a trial basis for experimentation. (Fig. 16) This was Clark's first "foot in the door" for operation on steamships in the Great Lakes.

Some time later, Clark invited the Senator to a demonstration of the wireless equipment on board the steamer. When the *City of Detroit* was five miles out from shore near Cleveland on Lake Erie, the Senator gave the ship's captain a message in a sealed envelope. In spite of poor weather with lightning and thunder, the message was correctly received at the station in the pavilion of the Belle Isle Boat Company. One copy of the message was delivered to the Detroit & Cleveland's dock and another copy of the message was carried to Senator McMillen's residence and given to the coachman.

Just a few days later, Senator McMillen telephoned Clark and told him that the message had been received and he was ready to install Clark wireless apparatus on the Detroit & Cleveland steamship line. Schantz had no choice but to follow orders.<sup>37</sup> The Detroit & Cleveland Navigation Company installed Clark's service in 1904.

A five kilowatt 500 Hz Clark wireless motor generator set took



the place of the pigeon loft on the third floor of the Detroit & Cleveland headquarters building. Ship captains carried pigeons on the boats so that if something happened they could release the pigeons which would then fly back for help with messages tied to their legs.

Clark began the reporting of the movements of boats past his wireless stations to the Lake Carrier's Association in Cleveland. He reported the progress of the next Detroit Yacht Club race on Lake St. Clair from the steamer *Pleasure* in the middle of the lake to the office of the Detroit & Cleveland line, from where it was picked up by the newspapers.

The lack of support from Mr. Schantz would come back later to haunt Clark in his fight with the giant and unscrupulous United

Wireless Company. The American De Forest Wireless Telegraph Company began to install stations at Erie, Pennsylvania and Cleveland, Ohio about this same time. They would directly compete with Clark's stations for business in the Great Lakes region. When De Forest's company was succeeded by United Wireless Telegraph Co., Schantz replaced Clark's equipment on the Detroit & Cleveland line with United Wireless gear.

### FIRST GOVERNMENT CONTRACTS

William MacKay, of the MacKay Engineering Company, was one of the visitors to the National Electrical Contractor's Association convention held in Detroit in 1903. He had seen the Clark Wireless Telegraph-Tele-

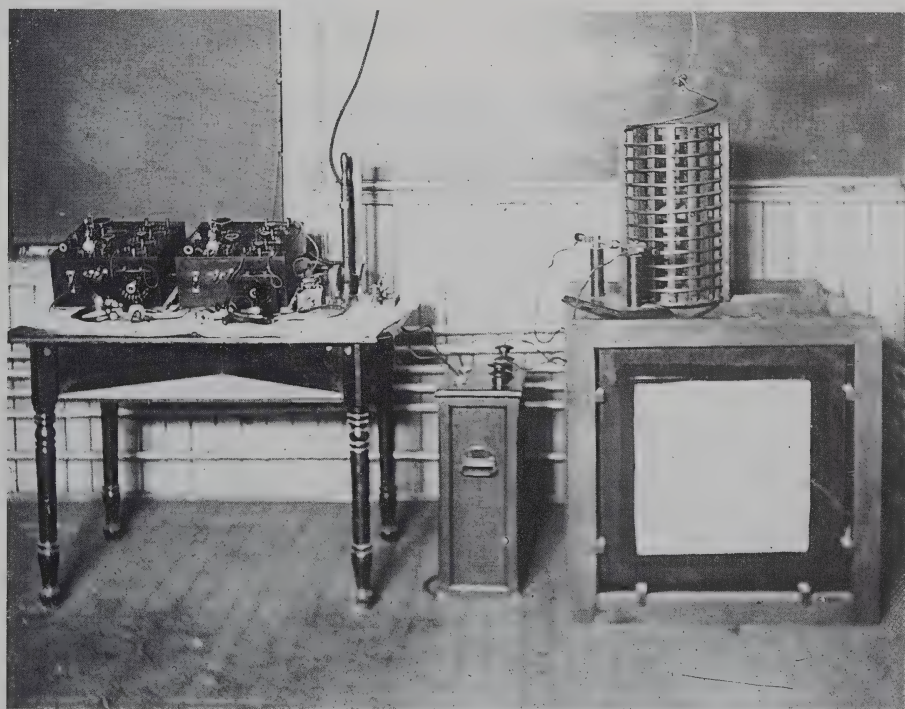


Fig. 16. Clark wireless test set for *Detroit & Cleveland* steamships. Photo is dated 1903. The transmitting equipment is on the right. Receiving equipment to the left. Photo source: TECLA historical archive.



phone exhibit there. MacKay did engineering work for the United States Navy and the War Department, and he told Chief Signal Officer Adolphus Greeley about Clark's progress with wireless and arranged for a meeting between the two men. This meeting and a demonstration that followed resulted in orders for Clark to build portable wireless sets for the United States Signal Corps as well as the Navy and the U.S. Revenue Cutter Service.

He received his first order for wireless from the United States War Department in December, 1903. These sets were some of the first portable wireless equipment ever ordered by the Signal Corps and Navy.<sup>38</sup> The first equipment delivered was relatively crude and was installed in the forts and harbors surrounding New York, including Fort Hancock at Sandy Hook, New York. However, as

time went on Clark's company made compact wireless sets in oak boxes that were particularly well suited to be carried by mules. Smaller portable wireless sets could be carried by two men. These portable sets had induction coils and were battery powered. They contained a multiple straight gap, two one-half gallon Leyden jars, coils and auxiliary apparatus. (Fig. 17)

The antenna for the Signal Corps portable sets was intended to be held aloft by a kite.<sup>39</sup> The Signal Corps kite, developed in conjunction with another order for sets from the Signal Corps in 1906, was called the "King Kite." The King Kite came in two sizes, a 6 foot version and a larger 7-1/2 foot kite. The kites held aloft a conducting wire that was attached to a special wire reel.

Clark also manufactured a wireless wagon set for the Signal

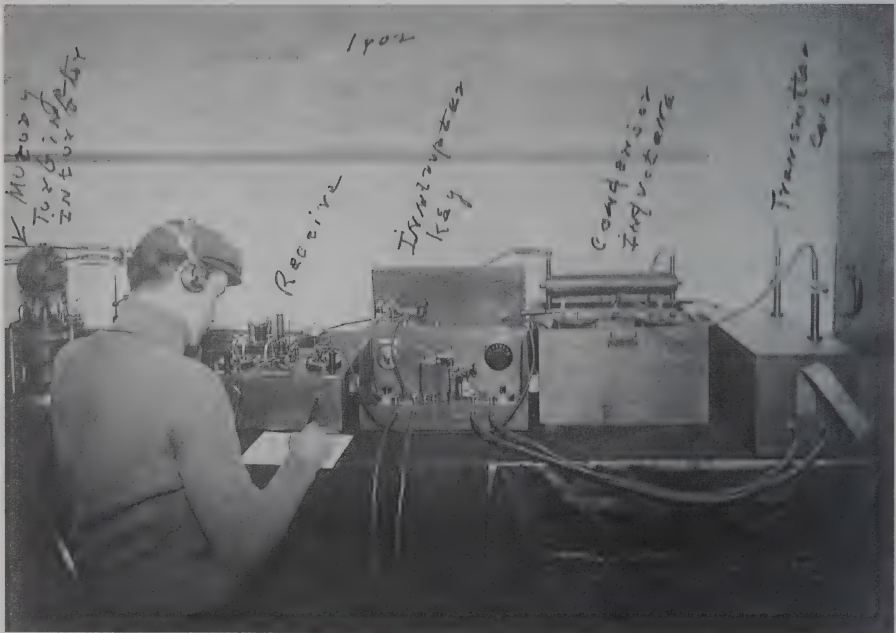


Fig. 17. Portable Clark wireless set of around 1902 with Lou Pike, Signal Corps operator at the operating position. Photo source: TECLA historical archive.

Corps. The wagon set contained a muffled spark gap and was also intended for use in the field. (Fig. 18)<sup>40</sup> A total of at least 48 Clark portable wireless telegraph sets were made, including several for the U.S. Navy. The sets purchased by the Navy were used in Cuba, on the Pacific Coast and in battle-ships.<sup>41</sup>

### CLARK PUBLISHES BULLETINS ILLUSTRATING WIRELESS SETS FOR SALE

In 1904, Thomas E. Clark Wireless Telegraph-Telephone Company began publishing its first bulletins and price lists (Fig. 19) for its wireless telegraph instruments<sup>42</sup>. The first page of the an early bulletin featured a drawing<sup>43</sup> of the Detroit & Cleveland's steamer *City of Detroit* in com-

munication with a Clark wireless station in Detroit. The bulletin states that, "We beg to inform you that we have opened up a wireless telegraph-telephone factory for the manufacture of wireless telegraph-telephone instruments," and that "In the first issue of our catalog we aim to bring out the best apparatus."

The bulletin seems to suggest a separate catalog would be issued, but instead it appears that the company simply chose to issue frequent bulletins.<sup>44</sup> In a photograph in the early brochures, Clark no longer appears nervous and awkward as he had appeared in Chicago in 1893. (Fig. 20) Now, Clark looks and sounds confident and in control as he tells the reader, "We beg to inform you that we are the pioneers in the wireless field for the manufactur-

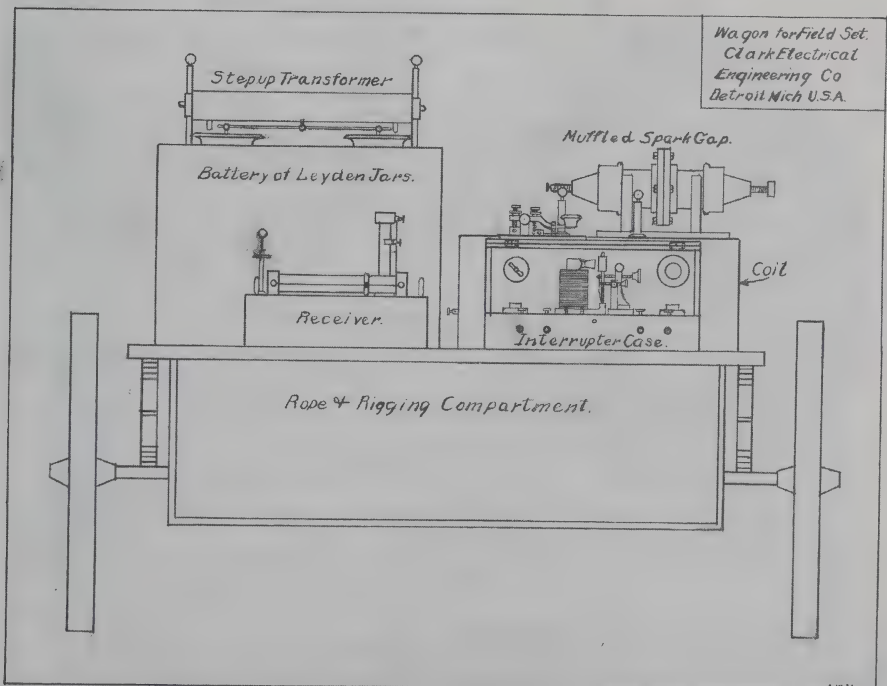


Fig. 18. Wagon set with spark gap wireless set made by Clark, undated drawing about 1905. Photo source: TECLA historical archive.

## TRANSMITTING AND RECEIVING

### Extra and Special Parts Constantly on Hand

COHERERS, Adjustable for Experimental Work.....	\$ 2.50
COHERERS, Long Distance, very high efficiency.....	5.00
SEALED COHERERS.....	10.00
RELAYS—Special Wireless, 1000 Ohms, Split Core.....	10.00
RELAYS—Special for Experimental Work, 250 Ohms, Split Core.....	5.00
TAPPERS.....	5.00
COILS, 1½ Inch Spark.....	20.00
COILS, 2 Inch Spark.....	25.00

Fig. 19. First price list of early wireless equipment offered by Clark in 1904.  
Photo source: TECLA historical archive.

ing of Wireless Telegraph Instruments in this country.” He reminds the readers, some of whom were likely poorly informed about wireless, that no wires are needed to communicate by the Clark wireless system. He also mentions that the Clark system is fully protected by patents owned by the company. The first wireless sets

offered in the bulletins are the Class A, Class B, Class C No.1, Class D, and Class H. Each set included both a transmitter and a coherer receiver. There was quite a bit of variability in the appearance of the sets between the different bulletins.

The Class A set was intended for long distance transmission and could be powered by batteries or a 110 volt circuit. It was offered with a mechanical circuit breaker or liquid interrupter. (Fig. 21) The Class A Wireless Telegraph Set was the set specially designed for and sold to the United States Signal Corps in 1903. Class A instruments were the type that Clark had recently installed for the United States government wireless telegraph station for Fort Hancock at Sandy Hook, New York. This station, which communicated with stations on Staten Island and Bedloes Island, used the Statue of Liberty to form a mast for the station.

The Class B Wireless Telegraph instruments were also built for long distance transmission but were only intended for use with dry cells and also included headphones. The Class B instruments were larger than the Class A set and they were intended for commercial use.

The Class C sets, also known



THOMAS E. CLARK  
FOUNDER AND INVENTOR  
CLARK WIRELESS TELEGRAPH SYSTEM

Fig. 20. Much more confident appearing Thomas E. Clark, founder and inventor of Clark Wireless Telegraph System. From Clark bulletin about 1904. Photo source: TECLA historical archive.



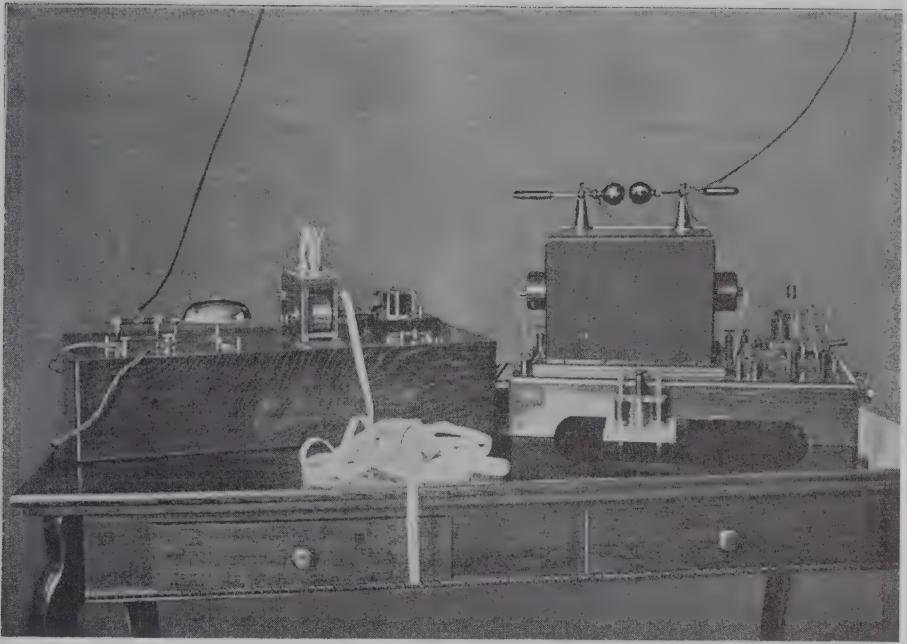


Fig. 21. Clark's Class A transmitter and receiver of 1904 intended for long distance transmission. The transmitter is on the right and the coherer receiver with tape register is on the left. Photo source: TECLA historical archive.

in the bulletins as Standard Sets, were built for short one to five mile distance transmission and

were intended for use as demonstration sets for colleges, students and in experimental work. (Fig.

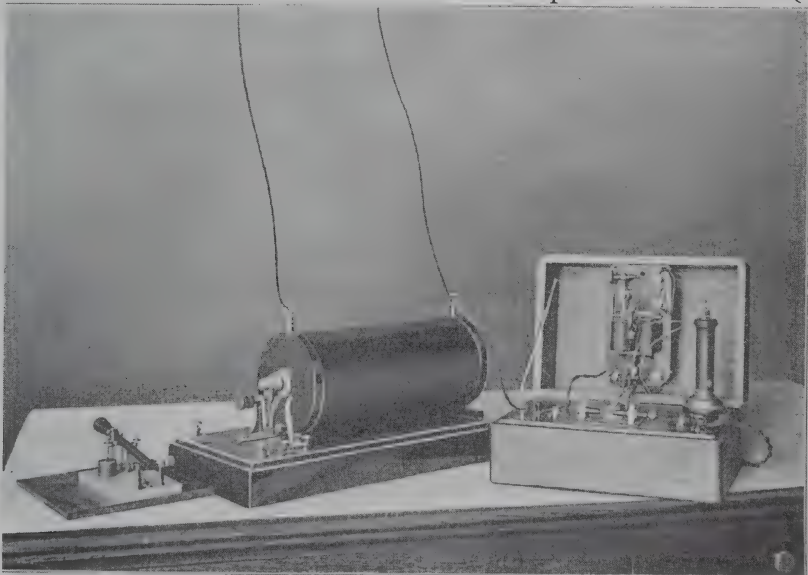


Fig. 22. Clark Class C wireless instruments for colleges, students and experimental work. The expected range was one to five miles. Photo source: TECLA historical archive.

22) The Class C set was the model Clark had exhibited at the 1903 Electrical Contractor's convention. The Class C set came in six models, named the Class C set No.1 through Class C set No.6:

- |              |                    |
|--------------|--------------------|
| Class C No.1 | Laboratory sets    |
| Class C No.2 | Lecture sets       |
| Class C No.3 | Student sets       |
| Class C No.4 | Demonstration sets |

- |              |                            |
|--------------|----------------------------|
| Class C No.5 | Experimental sets          |
| Class C No.6 | Miniature & Amusement sets |
- These sets differed slightly in cost, appearance, and accessories. The Foote Pierson Twentieth Century Key is occasionally shown in the bulletin photo cuts along with the Class A and Class C sets. The

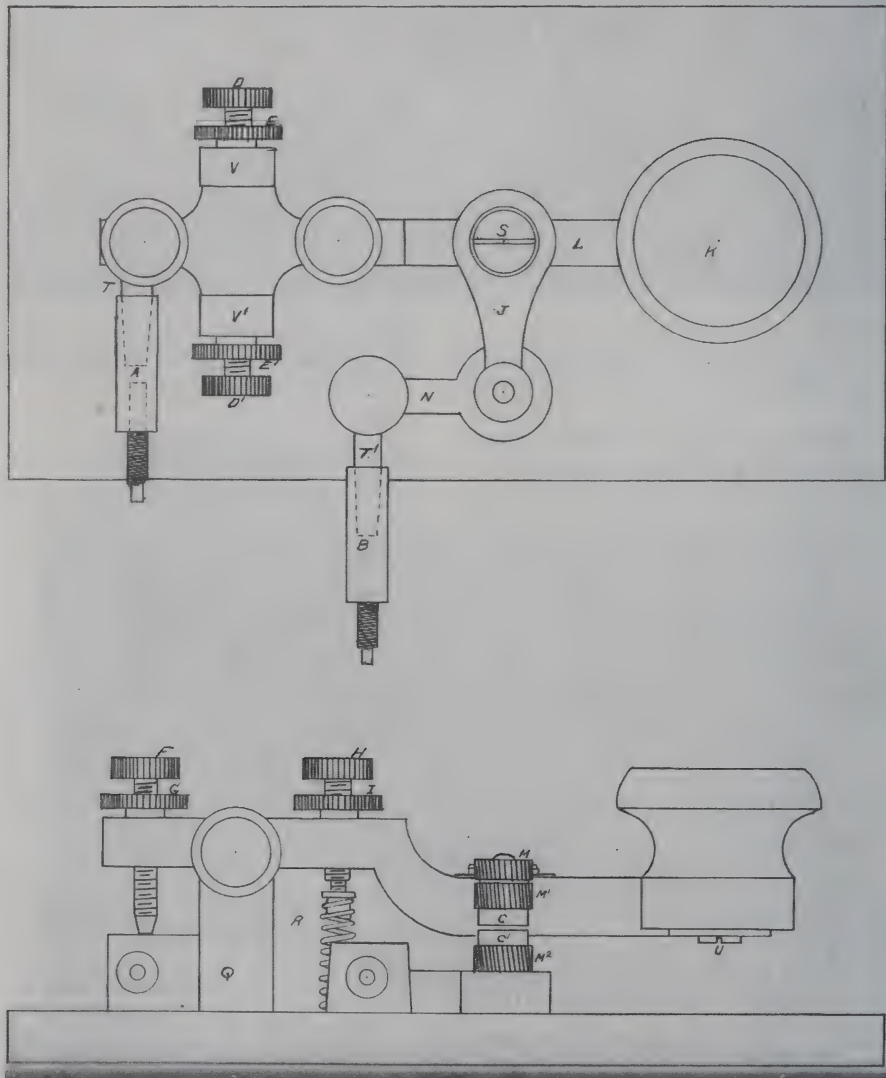


Fig. 23. Pencil on heavy paper drawing of telegraph key made by Clark for spark transmitters, about 1905. This key was made with heavy platinum contacts. Photo source: TECLA historical archive.

higher power commercial Class B sets are more likely to be shown with the telegraph key Clark designed himself. (Fig. 23)

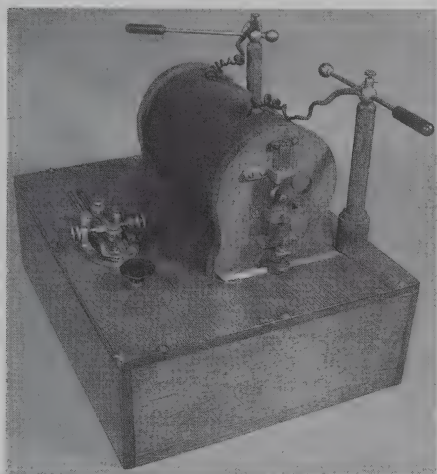


Fig. 24. Class D Clark experimental wireless telegraph set with Manhattan Electric Supply Company telegraph key. The label on the set reads "Clark-Wireless Instruments, Detroit, Mich." and the coil is rated for 4 amperes at 10 volts. Photo source: Detroit Historical Museum.

The Class D set was advertised in a flyer around 1907. Developed in response to demand, it did not appear in the earlier bulletins. It was considered a high grade but experimental wireless set. (Fig. 24)

Automatic wireless telegraph equipment made for experimental work and marketed under the designation "Class H" (Fig. 25) could repeat any letter of the Morse alphabet at a fixed interval.

The bulletins mention that Clark was in the process of building more land stations on the Great Lakes, stretching from Buffalo, New York, to Duluth, Minnesota. Eventually, Clark succeeded in installing about twenty land stations on the Great Lakes. One of the early bulletins further states that the company was prepared to "furnish estimates for Wireless Equipment for steamships, yachts, and vessels of all kinds; also for Private Wireless Stations on Land, Life Savings

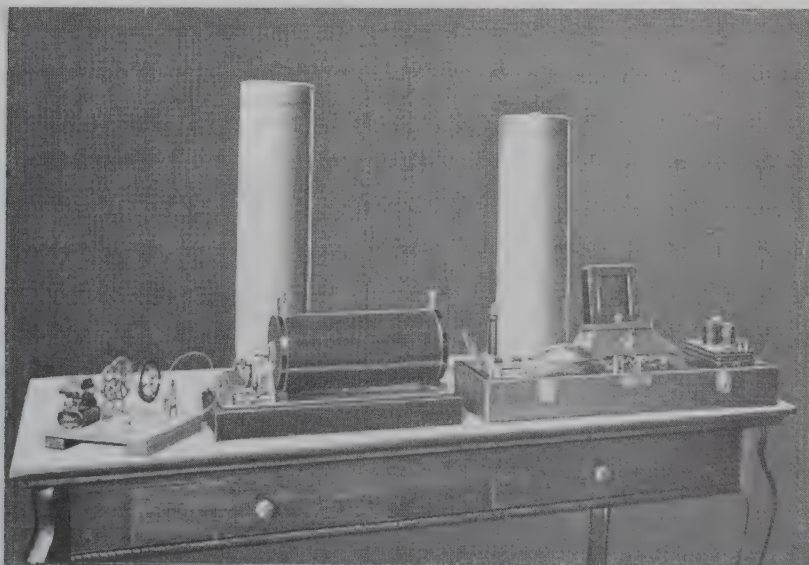


Fig. 25. Clark Class "H" automatic wireless telegraph equipment. The large cylinders are "copper capacity drums." The motor driven gears on the left send a pre-set signal repetitively. The induction coil and mechanical interrupter are in the center. The coherer receiver is on the right. Photo source: TECLA historical archive.



Stations and Light Houses. Railroads equipped with Automatic Wireless Signals. Mines furnished with Wireless Telegraph Sets<sup>45</sup>".

## YEARS OF RAPID EXPANSION

During the five years between 1905 and 1910, Clark was occupied with building commercial land stations and placing as many Clark Wireless System sets on boats on the Great Lakes as was possible. (Fig. 26) Most of these ships belonged to the Detroit & Cleveland fleet, the Buffalo & Cleveland line, the Detroit & Buffalo Company, or the Buffalo & Susquehanna Steamship Company.

The typical Clark shipboard station ran 3 kilowatts and operated at about 500 meters wavelength. Clark had small folded cards made up in order to invite passengers on the steamships to send messages to their friends and family.

Clark reminisced in 1951

about one particular passenger who had been on a Detroit & Cleveland ship. He told the woman that he could send a "wireless" telegram to let her friends know she was arriving. She laughed, saying "The only way you can a message to the land is to throw somebody overboard who can swim faster than this boat can go." Clark sent the message anyway and when the boat docked, the woman's friends were standing there to meet her. She could hardly believe it.<sup>46</sup>

Land stations were built in Milwaukee, Buffalo (Fig. 27), Cleveland, Detroit (Fig. 28), Port Huron (Fig. 29), Bay City, Ashtabula, Erie, St. Thomas, Duluth, Marquette, Sault Ste. Marie, Saginaw and Toledo. These land stations produced between 5 and 25 kilowatts of power. Clark even designed a 35 kilowatt station, although it apparently was never installed.<sup>47</sup>

Most of these stations were open 24 hours every day for pub-

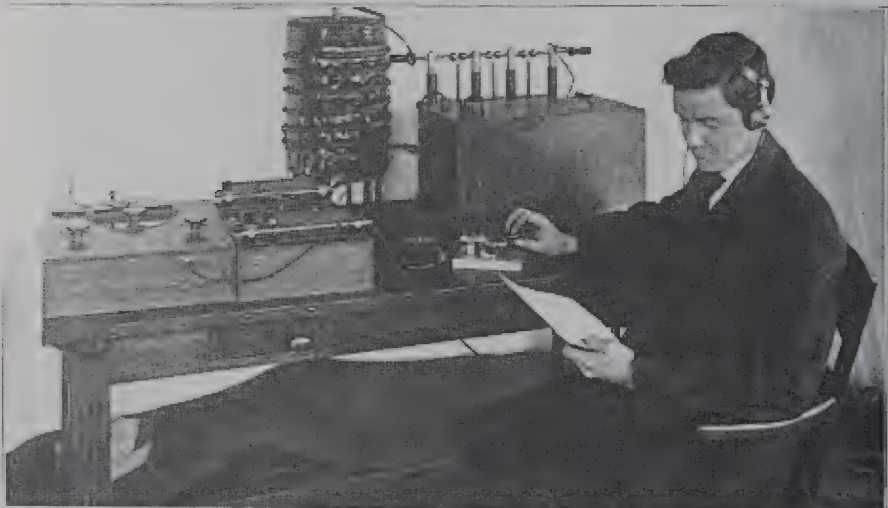


Fig. 26. Type of Clark wireless telegraph apparatus used on steamships. Notice interesting multiple spark gap on the right. The oscillation transformer is in the center and the receiver is on the left. Photo source: TECLA historical archive.

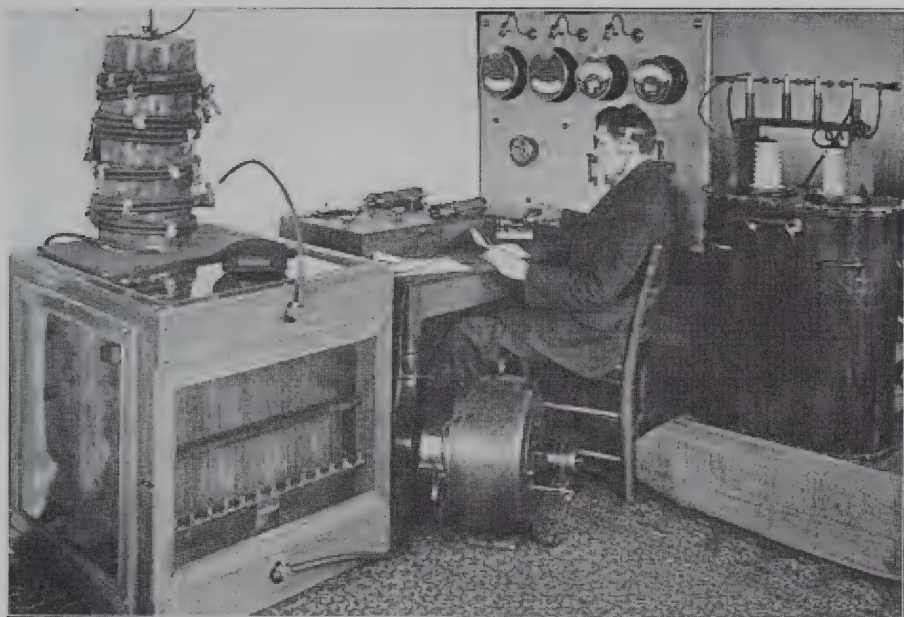


Fig. 27. Interior view of Clark wireless telegraph station, Buffalo, New York, ca. 1905-1910. The receiver is on the desktop. The operator is manipulating the telegraph key. The apparatus on the far left is a plate glass condenser box and the oscillation transformer. There is a large transformer with white insulators and a multiple gap to the right of the operator. Photo source: TECLA historical archive.



Fig. 28. Clark wireless station at the foot of Wayne Street in Detroit. Undated photograph but probably about 1907. The receiving equipment and telegraph key are on the desk to the left. The "jump rope" type pull handle hanging from the ceiling typically attached to a lightning or antenna switch and acted as a quick disconnect in an emergency. Photo source: Detroit Historical Museum.





Fig. 29. Clark wireless telegraph station, Port Huron, Michigan, 10 K.W. capacity. This station in 1907 reported over 25,000 vessel passages and was in daily communication with Buffalo, N.Y. covering a distance of over 200 miles overland. Photo source: TECLA historical archive.

lic service. All told, the ten high power Clark wireless stations operating in the Great Lakes in 1907 area handled over 70,000 messages in one eight month period.<sup>48</sup>

They received signal reports from thousands of miles away. Remote stations in locations such as Guantanamo Bay, Cuba and United States government stations in Panama reported receiving signals from Clark wireless stations in the Great Lakes area.<sup>49</sup>

In 1906, the Detroit & Cleveland Navigation Company contracted with Clark to transmit election results to its ships in the Great Lakes. This was the first known "incursion of politics into radio."<sup>50</sup>

At the same time Clark was developing wireless telegraphy, he

continued to work on experiments in wireless voice transmission on a daily basis. He developed and demonstrated a functional wireless telephone as early as 1906. (Fig. 30) He knew from early experiments that spark transmitters were not suitable for telephony work, and wrote in 1908 that "The success attained in the wireless telegraph field has long kept awake the hope of a practical realization of wireless telephone, but as long as the violent jerky spark as used in wireless telegraph was the only source, the fulfillment of the hope was not to be thought of."<sup>51</sup>

Thus realizing that he needed a source of continuous waves to transmit voice, rather than the damped waves of a spark



transmitter, he used Elihu Thomson's speaking arc as the basis for his radiotelephone. He also gives credit to Simons, Duddell and Poulsen for their pioneering work with arc transmitters. He noted that the arc transmitter reproduced the tones of the human voice perfectly once the receiving and transmitting stations were both properly adjusted, and he found that electrolytic detectors worked well to receive the signal.

He placed an experimental arc transmitter on board the steamer *City of Detroit* and was able to maintain constant communication with it for a distance of over thirty miles while it traveled from Detroit to Cleveland in 1907. By June of 1908, passengers were able to talk over a distance of about 25 miles from the steamer *City of Cleveland* to the Clark wireless station at the foot of Wayne Street in Detroit. Clark advertised that he was able to patch wire telephone lines directly into a wireless telephone transmitter.<sup>52</sup>

Clark organized more companies to handle various portions of the business. The Clark Wireless Telegraph & Telephone Company was organized in 1907 under the laws of Arizona, presumably because of more favorable tax or legal details. The officers of the new company represented the top businessmen at the time in Detroit. R.R. Sterling, who made money in the automobile industry, was the president of the



Fig. 30. Clark Wireless Telephone, probably about 1907. The apparatus is an arc transmitter. Thomas E. Clark is the operator. Photo source: TECLA historical archive.

company. Thomas E. Clark himself was the vice-president. Norval Hawkins, who was sales manager of the Ford Motor Company, was the secretary. Hawkins had become rich with the Ford Company after Henry Ford agreed to pay him one dollar for every model T over the first million sold.<sup>53</sup> Clark held Norval Hawkins in such high regard that he named his youngest son after him.

The Clark Wireless Telegraph & Telephone Company assumed the business, property and stock of the Clark Electric Engineering Company and the Clark Wireless Telegraph Company (Fig. 31), which had been incorporated in 1906. The Clark Wireless Development Company was organized in 1905, and the International Clark Wireless Telegraph Company was incorporated in



Fig. 31. Letterhead designed by Thomas E. Clark. Clark Wireless Telegraph Company was incorporated in 1906 and then superseded by the Clark Wireless Telegraph and Telephone Company a year later. The original color of the letterhead was shades of blue. Photo source: TECLA historical archive.

1906 in Augusta, Maine.

Any final doubts that Clark might have had regarding whether wireless could be made commercially profitable had been erased by now. Clark Wireless

Telegraph & Telephone Company soon issued more of the undated Clark Wireless Bulletins in relatively quick succession. Clark Wireless Bulletin No. 6 specifically promoted the Class "C" set which it now called the "Junior" Type wireless set for communication over distances from one to five miles. The Class "C" or "Junior" Type set could be bought for a base price of \$25. Clark offered another small wireless set called the "Baby Jr., Type J." The youngster in the advertising photo is almost certainly Clark's son James after whom the set is likely named. (Fig. 32)

Bulletin No. 7 in-

cluded a spare parts list (Fig. 33) showing quite a wide range of wireless products including Leyden jars, spark coils, telegraph keys, coherers, and spark gaps. Some of the parts were made by

DO YOU VALUE GOOD WORK ?

## Clark's Wireless Apparatus

FILLS THE GAPS.



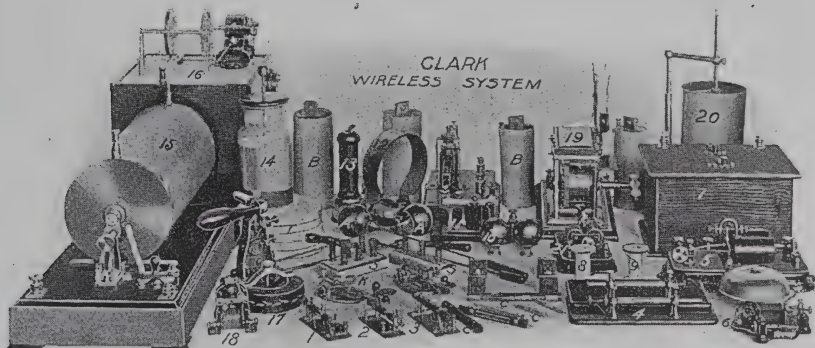
"BABY JR." TYPE "J."

Fig. 32. Clark wireless set "Baby Jr., Type J" which was probably named after his son James. The youngster in the photo is James Clark. Photo source: Detroit Historical Museum.

THOS. E. CLARK WIRELESS TELEGRAPH-TELEPHONE CO., DETROIT, MICH.

## Clark's Marvelous Invention

An apparatus to fill Commercial and Experimental Gaps; Costs Little, Operates Correctly, Wears Longest; looks more perfect than any apparatus on the market.



The above cut shows extra parts always on hand. Anything in the line of apparatus or extra parts for the Etheric Waves.

### Classified Extra Parts, as Above Cut, Set Forth by Number.

- |  |   |
|--|---|
| <p>1 } Adjustable Cohers placed in Receiving Clips, mounted on polished hard rubber base.</p> <p>3 Vacuum Scaled Coherer. Letters C-C shows sealed Coherer detached from holder or receiving stand and clasped firmly in metal jaws, binding posts attached to metal clips.</p> <p>4 Coherer, mounted on polished mahogany wood base, with taper attached.</p> <p>5 Special Clark Wireless Relay.</p> <p>6 Electric Pivoted Gong and Tapper, with Back Stroke attachment.</p> <p>7 Adjustable Inductive Capacity.</p> <p>8 } Shunt Coils for Receiving Circuit.</p> <p>10 Spherical Brass or Copper Balls for Transmitter Gap.</p> <p>11 Special Clark Wireless Sounder for taking the Morse Code in dots and dashes.</p> <p>12 Pony Telephone Receiver, with head band attachment for taking the dots and dashes by the microphonic receiver.</p> | <p>14 Leyden Jars, in pint and quart sizes.</p> <p>15 Clark High-frequency Coils, manufactured in sizes giving from <math>\frac{1}{2}</math> inch to 18 inch spark.</p> <p>16 Automatic Circuit Breaker or Mercury Interrupter.</p> <p>17 Transmitting Key with heavy Platinum Points, Shunt Coils and Condensers.</p> <p>18 Battery or Power Motor for running Circuit Breaker or Mercury Interrupter.</p> <p>19 Special Clark Wireless Telegraph. Morse register with Automatic Self-starting, Stopping, Inking and Writing attachments.</p> <p>20 Liquid Interrupter, adjustable for Battery Circuit, 110 to 220 Volts.</p> <p>BB Dry Batteries for Receiver Circuit.</p> <p>K Morse Key.</p> <p>XX Choke Coils.</p> <p>AA Spherical Ball with metal rods attached to hard rubber handles, complete and ready for Spark Gap.</p> |
|--|---|

Write for AGENCY to Main Office, DETROIT, MICH.

Fig. 33. Extra parts list for "Clark's Marvelous Invention." From Clark Wireless Bulletin No. 7. The picture shows a wide array of parts including telegraph keys, a register, induction coil with mechanical interrupter, Leyden jar, spark gaps, coherers, etc. Photo source: TECLA historical archive.



Clark, others obviously were not. The Footé Pierson & Co. Twentieth Century key is easily recognized. The cover drawing on Bulletin No. 7 (Fig. 34) is of the factory and laboratory in Pontiac, Michigan. Interestingly, the Clark factory shown in the drawing only existed for a short time. Clark did occupy the space in Pontiac, Michigan, and made wireless sets there.

Clark said that the people of Pontiac built the factory for him but that he could not get financing to keep operating there. In addition to lack of financial backing in Pontiac, the accommodations were not acceptable in part because it was too great a distance to the Great Lakes. The Pontiac site was soon turned over to an automobile company.

Bulletin No. 8 notes that Clark manufactured coils from 1/2 inch up to 24 inch spark, an

enormous discharge considering that a discharge of just 3 inches requires tens of thousands of volts! Bulletin No. 10 pictured the Long Distance Station Type Instrument, especially recommended for working distances from 100 to 1500 miles.

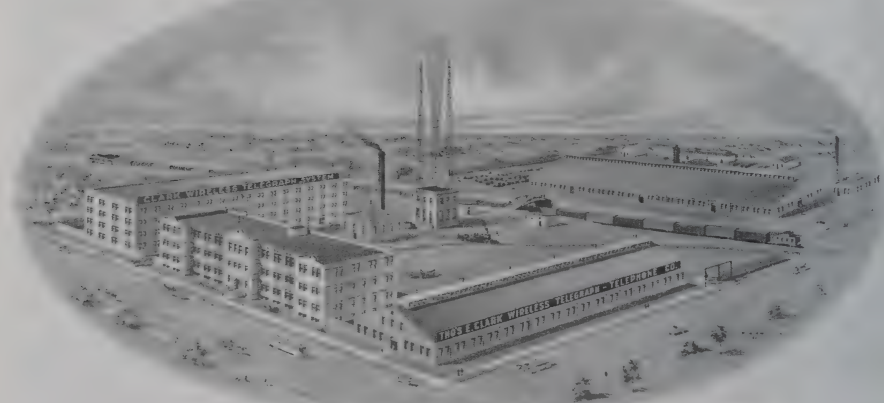
In 1908 Clark designed his first valve receiver. The schematic is dated Jan. 1, 1908, and it appears to illustrate a circuit using two Fleming valves (Fig. 35). Using the terminology of the day, the unit is called a Wireless Valve Tuner. No record remains of whether he sold any of them.

## INVOLVEMENT OF THE PRESS

Storms took an awful toll on the Great Lakes at the time. In 1905, 213 lives and \$5,375,000 in property of were lost.<sup>54</sup> Clark wireless stations were able to re-

### THOS. E. CLARK WIRELESS TELEGRAPH-TELEPHONE CO.

—→BULLETIN No. 7, 4←—



Main Office--DETROIT, MICH.

Factory and Laboratory--PONTIAC, MICH.

Fig. 34. Cover drawing on Clark Bulletin No.7 showing the factory and laboratory in Pontiac, Michigan. This facility was only occupied by Clark for a short time. In reality, it may not have been as extensive a facility as portrayed here.

Photo source: TECLA historical archive.

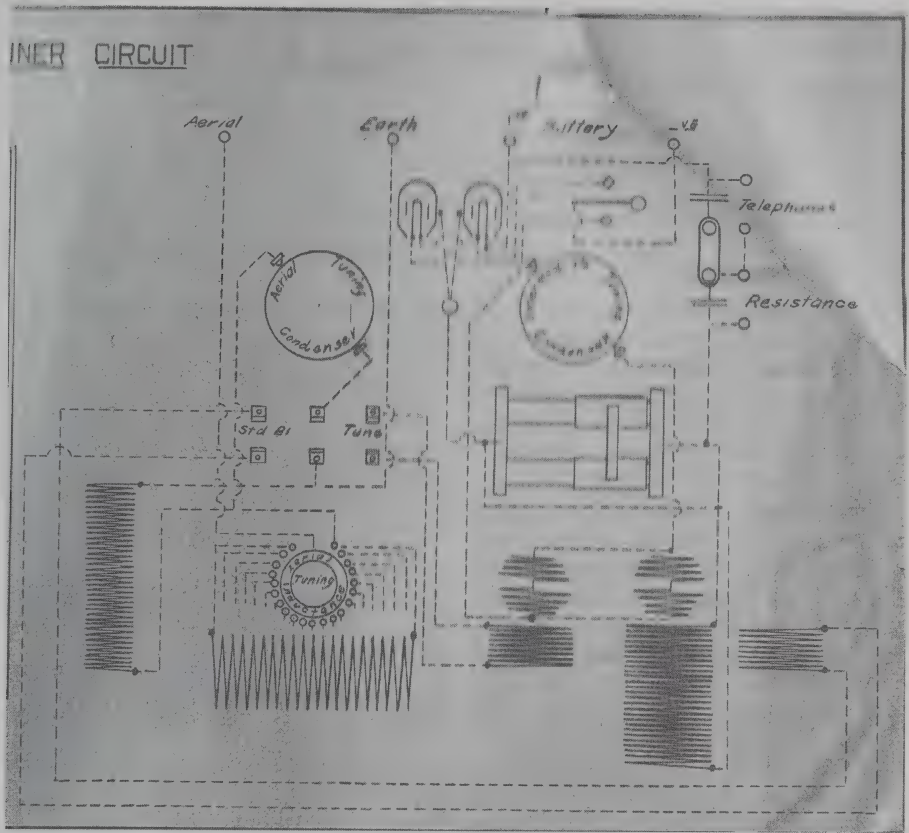


Fig. 35. Drawing of Wireless Valve Tuner Circuit dated Jan. 1, 1908 and signed by Thomas E. Clark, E.E. The dark and light shades have been reversed to aid in reading. Photo source: TECLA historical archive.

port information on collisions on the Great Lakes and helped out when ships were in trouble or disabled. When the big steamer *City of Cleveland* was stranded in fog with a broken rudder, she was able to report the problem to her home station by wireless. On another occasion, when the steamer *George Stone* wrecked in 65 mile per hour winds, her predicament was transmitted to shore and all eighteen lives saved when wrecking tugs were sent.

The press began to recognize the usefulness of Clark wireless on board ship. Press coverage was intense when Jack Binns, the radio operator on board the steamer

*Republic*, saved 1,700 lives when that ship was rammed by the steamer *Florida* in 1909 while in the Atlantic Ocean. As a result of this, public pressure to place wireless on ships on the Great Lakes increased markedly.

The newspapers reported how wireless would save lives if large passenger ships on Lake Erie were wrecked far from land. C.F. Overturf, wireless operator at one of the Detroit stations, was quoted by the *Detroit Press*, noting that "Wireless telegraphy is the greatest life saving device for vessels at sea that has been invented." The Lake Carrier's Association was ready to help Clark wireless if

funds were needed to build more stations.<sup>55</sup>

Beginning about 1907, Clark began installing several wireless stations for newspapers. These included the Detroit Journal, Port Huron Herald, Alpena News, Bay City Tribune, and the Saginaw News. Each time a station was erected in one of these offices, the newspaper splashed the headlines across its front page. Usually these stories included an invitation to a demonstration of the wireless apparatus and the opening ceremonies.

When the wireless station opened with a demonstration of the apparatus in June, 1909, at the offices of the Bay City Tribune in Bay City, Michigan, Clark was present to make some comments. Looking toward the future, he said with his characteristic humility that, "I will ask no greater reward than to hand down to posterity the name of having done something to contribute to the safety and happiness of mankind."<sup>56</sup> In fact, Clark later stated in an interview in 1956 that he never made any money on wireless but ploughed all the profit from that part of the business right back into research and development.

Sometimes the newspapers also included related stories to pique the public's interest. For example, when the Alpena News station began wireless operations in 1909, it reported that it would be "Tiny Miss Lucy Updegraff" who would send the first wireless with her "little fingers on the wireless key."

In the same issue, the Alpena News reported that "A Message From Mars Will Come—No Joke." Supposedly quoting Thomas E. Clark, they wrote that "Mars has been sending wireless messages for some time past to

the different aerial stations. Marconi and others besides ourselves hear from that planet daily. If it is not Mars, we are at a loss to place the keyman for messages not in Morse code are surely being received at diem intervals, and the dots and dashes are received on the earth's instruments."<sup>57</sup>

## CONTINENTAL WIRELESS TELEPHONE & TELEGRAPH COMPANY

Starting in 1904 when the De Forest Wireless Telegraph Company began operating in the Great Lakes area, Clark began having to compete for business. The competition was amiable, aided by the fact that Clark and De Forest were friendly acquaintances.<sup>58</sup>

However, the competitive environment was rocked when the United Wireless Telegraph Company took over control of the De Forest company in 1907. United Wireless intended to drive Clark Wireless Telegraph and Telephone Company off of the Great Lakes and even published newspaper articles to that effect. United Wireless was aided by the lack of regulation in the new wireless telegraph industry. Intentional jamming of wireless signals was not outlawed until 1912. This allowed United Wireless stations to maliciously jam wireless transmissions from the Clark stations so that they could no longer communicate with ships or each other. Clark was unable to get a single message through at times.

United Wireless was unscrupulous in its attempt to ruin Clark. There were episodes of radio masts found cut down and emery powder dumped into generators to ruin the bearings.<sup>59</sup> United Wireless found ways of



undercutting Clark with clients. Clark charged his customers a few cents per word to send a wireless telegram, as did other operating companies in order to generate revenue. However, United Wireless rarely charged for its equipment or the messages it sent.<sup>60</sup> Steamers using the Clark system of wireless paid the shipboard telegraph operator's salary by agreement while Clark paid the salary of the land operators. United Wireless did not require steamship companies to pay the operators so that both the telegraph operator and the equipment came on board free of charge. United Wireless also had an extensive business on the east coast, while Clark operated only in the Great Lakes area.

A "bitter fight"<sup>61</sup> ensued for all these reasons between Clark and United Wireless. Directly as a result of the United Wireless situation and in a fight for its survival, the Clark Wireless Telegraph & Telephone Company joined in the formation of the Continental Wireless Telephone & Telegraph Company in December of 1909. Continental Wireless was formed by the merger of Clark's company, the Collins Wireless Telegraph Company, the Pacific Wireless Telegraph Company, and the Massie Wireless Telegraph Company.

After consolidating with Continental, Clark became its Vice-President and General Manager. The men who led these companies knew each other well and respected each other. Massie was considered a pioneer in wireless on the east coast and an excellent engineer. A. Frederick Collins had approached Clark back in 1902 about a possible business relationship.<sup>62</sup>

The vision these men had at

this time was that of a coast-to-coast wireless network. Massie could provide the east coast part of the network, Clark and Collins had stations in the heartland of the country, and Pacific Wireless was the west coast link. It all must have looked quite promising at the outset, but the venture did not succeed. One of the biggest problems was that wireless telegraph had its best application with ships at sea and not over land where wire telegraphy was more reliable and already had infrastructure in place.

By mid 1910, Clark was losing the battle with United Wireless for the Great Lakes territory. He had gone to New York and had talked with C.C. Wilson, the president of United Wireless. Clark told Wilson that he was discrediting the whole new field of wireless. Wilson told Clark that he "didn't give a darn" and he laughed when Clark told him that the fight between United Wireless and Continental would cause them both to go under.<sup>63</sup> All Wilson wanted to do was make money and he did not care about the best interests of wireless.

Clark, in contrast, had put his heart and soul into the development of wireless. It was a difficult time. Clark had lost most of his customers and had to close most of the land stations he worked so hard to establish just a couple of years earlier. The final blow came when United Wireless sued Clark for patent infringement. The suit had little merit and was intended to harass Clark and drain what little resources the company had left. As part of its defense, Clark presented evidence to the Court that United Wireless had intended to destroy his business by fraudulent methods.<sup>64</sup> United Wireless had stolen Clark's

steamship contracts by offering to replace the stations at a financial loss. Finally, in July the suit against Clark was dismissed by the United States Circuit Court.<sup>65</sup>

The judgment was favorable, but it came much too late to save Clark Wireless Telegraph & Telephone Company. Because of financial losses, Clark ceased operations on the Great Lakes by the end of 1910. The remaining land stations were closed, equipment taken off the boats, and the Clark Wireless Telegraph & Telephone Company was out of business.

Federal authorities raided the United Wireless offices in June, 1910. The company had been selling worthless stock to support its fraudulent business practices. Schantz, who had replaced Clark's equipment on D&C steamships with the free United Wireless equipment and operators, only had their services for six months. The fraud trial of United Wireless executives including C.C. Wilson concluded on May 29, 1911. Wilson went to the U.S. Penitentiary in Atlanta and later died in jail.

After the raid, Clark published a notice in the New York Times stating that the Clark Wireless Telegraph Company was not a subsidiary of Continental Wireless and that he was not an officer. He told the newspaper that it was mainly due to the information he himself had furnished the government inspectors that the raid was made.<sup>66</sup>

The next year Marconi Wireless Telegraph Company sued United Wireless for patent infringement and as a result took over United Wireless. As a final footnote to this dirty business, in December, 1911, after Clark and Massie were well out of the picture, four officers of Continental

Wireless were indicted on fraud charges similar to those pressed on United Wireless just a year earlier. They were likewise convicted and served prison terms of up to four years. Continental Wireless was dissolved.

## IN BETWEEN YEARS

After withdrawing from the Great Lakes, Thomas E. Clark fell back on his government contracts for income. He received another order for portable sets from the Signal Corps about 1910.<sup>67</sup> He received a second inquiry from the Japanese government regarding possible purchase of wireless equipment through a recommendation from Lee de Forest.<sup>68</sup>

However, the endeavor into which Clark now devoted his greatest energy was automatic train control and railway safety. (Fig. 36) He had begun preliminary research into wireless control of locomotives, railroad safety, and ways to avoid collisions years earlier. Now it became his priority. He developed new braking equipment, relays, and control systems.

He patented dozens of these inventions after testing them on full size railroad models he built in the laboratory area of the factory. He applied for the first of these patents in 1912, and continued work on railway signaling and control all the way up to 1930. (Fig. 37) He superimposed radio waves on the track rails and controlled them through the track relay circuit. Automobiles near the railway would be sensed by coils within the roadway. Of the approximately 40 patents granted to Clark in the United States, about 30 of them relate to this line of work. Internationally, Clark held about 94 patents, again mostly concerning automatic

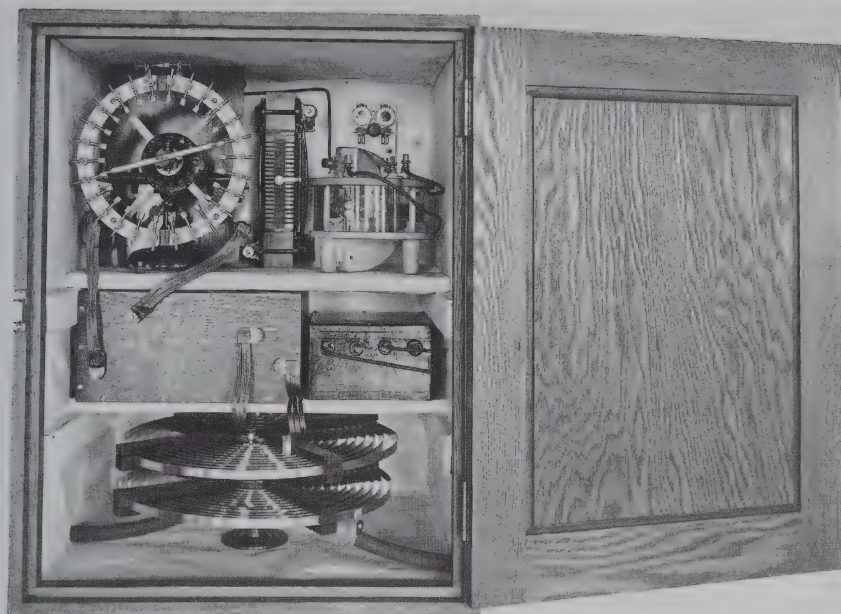


Fig. 36. High Frequency Wireless Control Station for Railroad Signaling made by Thomas E. Clark. The similarity between this equipment and the Clark system of wireless telegraph is striking. A rotary spark gap is easily visible on the upper left, as is a pancake oscillation transformer on the bottom shelf and probably an induction coil and condenser on the middle shelf. The additional equipment on the upper right is the extra equipment for railroad signaling. The photo is undated. Photo source: TECLA historical archive.

railroad train control. These systems were patented in France, England, Germany, Belgium, Hungary, Australia<sup>69</sup> and elsewhere.

This time, politics would thwart Clark and prevent him from ultimately achieving the degree of success for which he had hoped. He was able to work with the Westinghouse Company on a speed control that was installed on some railroad cars and locomotives of the Southern Railway. However, the automatic train control equipment was never ordered by the railroads even though he tested it successfully on the Michigan Central line.

One problem was that the railroad employees, including the engineers, would not back a sys-

tem on board the locomotive that might take control out of their hands. Clark said that, "They were like the captains on the boats who hated to have the manager from the telegraph office tell them what to do on the boat."<sup>70</sup> The Association of American Railroads Lobby in Washington did not back his system. Competitors also had a much larger marketing presence in the railroad industry than did Clark.

It could also be that luck had a hand in preventing the adoption of Clark's automatic train control system. Just as Clark was hopeful his system might be accepted in about 1928 and 1929, the Depression intervened.



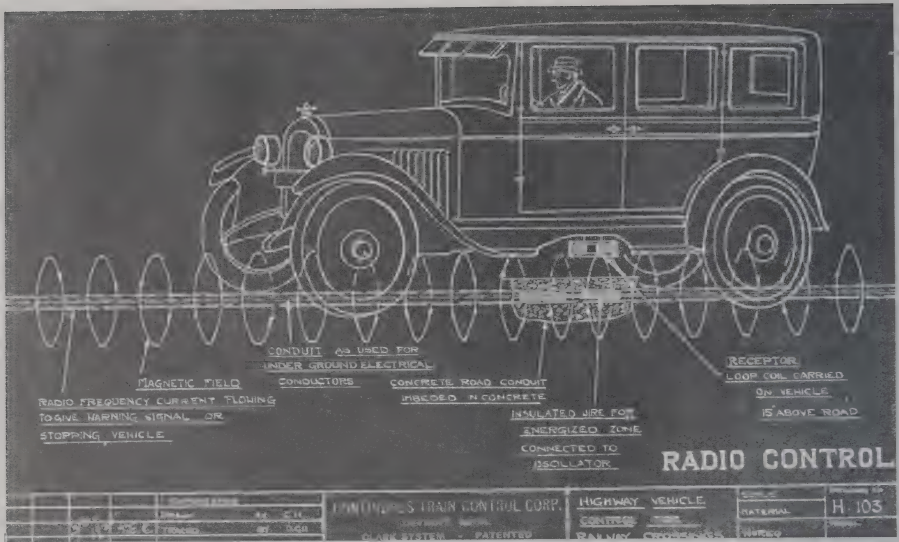


Fig. 37. Clark method of highway vehicle control for railway crossings. The drawing, dated 1925, shows an oscillator and conductors imbedded in the roadway and a receptor loop coil carried on the vehicle. Photo source: TECLA historical archive.

## TECLA

It did not take long for Thomas E. Clark to re-invent himself in his favorite endeavor, wireless. He called his new company “TECLA,” a contraction of his own name— **T.E. CLARK**. The first year that TECLA appeared in the Detroit city directory is 1916, and TECLA took out a full-page advertisement that year.<sup>71</sup> The factory was still at Cass & State Streets in Detroit. TECLA promoted its electrical laboratory with consulting engineers for electrical and mechanical problems, along with specialties in “Electrical measurements. Experimental work. Patent office models. Manufacturing of electric and mechanical specialties. Designing, testing, perfecting inventions. Electrical & mechanical railway signaling apparatus. Radio telegraph and telephone instruments and equipment.”<sup>72</sup>

In a full-size 6 page brochure that was probably printed

just before World War I, TECLA presented half tone photographs for a quenched gap panel type spark transmitter that could be built for 1/2 to 2 kW power capabilities. In the front view of the panel (Fig. 38), the new company logo appears to have been hastily applied for the photograph. This is the only spark transmitter that TECLA would commercially offer. It had a cast iron frame and a bakelite front panel upon which the meters, controls, and spark gap were mounted. The last page of the brochure showed a radio receiving set with loose couplers and crystal detectors. (Fig. 39) A few years later, at the Detroit Radio Show in 1922, a poster that was part of a historical review of radio at Clark’s booth declared that this transmitting panel set and the receiver were designed and manufactured by TECLA for the United States Navy. World War I got in the way of further progress for TECLA in 1917.

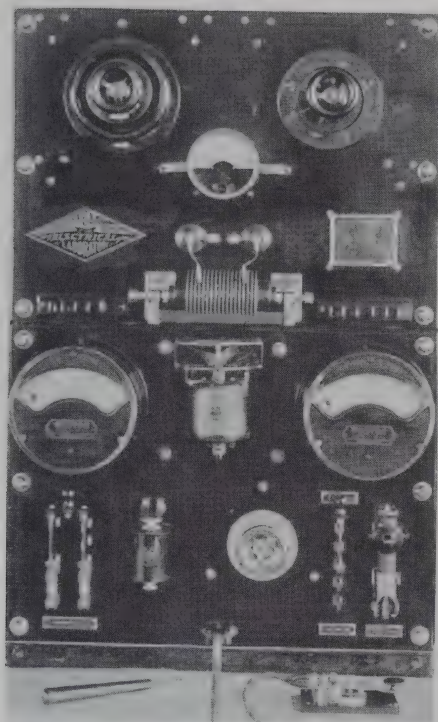


Fig. 38. TECLA Co. Quenched spark gap transmitter, front view, about 1916. The company logo on left center has been hastily applied. The quenched gap and cooling fan are in the center of the panel. The meters and circuit breakers are easily visible on the panel. The remaining components were mounted behind the panel. Photo source: Russ Kleinman & Karen Blisard collection.

## A LITTLE TIME TO RELAX

Clark needed a place for quiet time and recreation. After staking out a claim on Lake Huron a few hours from Detroit in Canada, he built a lovely cottage for the family on the shoreline where he grew huge zinnias about 1916.<sup>73</sup> At the time, the location was quite remote and sparsely populated. In order to get to the cottage, Clark had to take the ferry across to Canada and then travel up the coastline on a train or one lane dirt roads towards Sault Ste. Marie. The drive took two days back then and it was really quite an adventure. He grew raspberries and black currants at the cottage. Clark did not drink or drank very little.<sup>74</sup> He loved to cook and make ham and raspberry jelly sandwiches, and he had a wooden plank rowboat. Clark and Will Scripps were both avid birdwatchers and one summer they recorded bird calls together at the cottage.

Also in 1916, Tom and his wife Agnes accompanied their son James, who was born in 1897, and his new bride to Yellowstone Park. Yellowstone was flooded by rain that year, and they had to drive

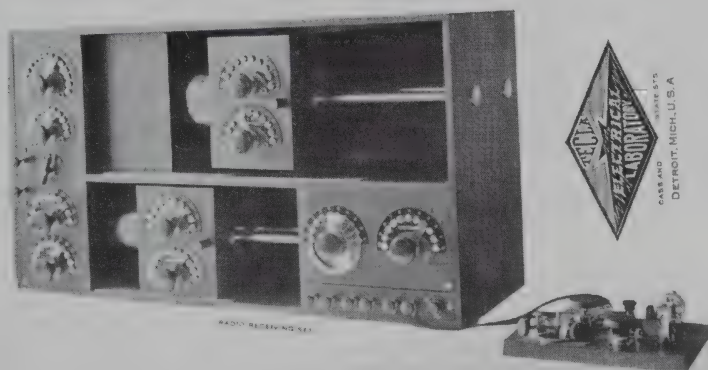


Fig. 39. TECLA Co. radio receiving set of about 1916 with multiple crystal detector. Advertised together with the quenched gap transmitter and not otherwise labeled. Photo: Russ Kleinman and Karen Blisard collection.



over railroad trestles to get there. They went through five tires on the trip. James kept the car running and at one point had to have a farmer weld the gas tank after they put a hole in it. (Fig. 40)

Thomas E. Clark belonged to the Masonic Temple in Detroit. He would thrill audiences there when he performed electric shows with a Tesla coil. He could throw lightning back and forth with the high voltage and stand his hair on end.<sup>75</sup>

## WORLD WAR I

With the onset of World

War I, most radio activity except for military applications stopped. TECLA was a new business and unlike the established wireless manufacturing companies it was not a major supplier to the United States Navy or Signal Corps during the war.<sup>76</sup> TECLA was probably mostly idle during the war except for small jobs. Some of the factory's workers may have volunteered for the military. Clark mentioned that during World War I he spent some time in Anacostia, which was in the area of Washington, D.C. He used the time to discuss radio investiga-



Fig. 40. The Clark family in a photo taken about 1918. Thomas E. Clark is standing next to his youngest son Norval who is on the running board. His wife Agnes is in the driver's seat. Thomas Laing Clark is next to his father and James Edward Clark is on the far right. The car is a Chalmers Touring Car, probably the 1917 model. The circular pattern on the street is caused by the wooden paving. The scene is in front of the Clark residence at the corner of Avery and Alexandrine. Ty Cobb lived in a house just off the right side of the photo. Photo source: Clark family records, with information about the photo written by Dick Clark on January 15, 1996.



tions with Dr. Hoyt Taylor of the United States Navy. It is doubtful though that Clark was actually hired in any capacity by the military during the war.

These were lean years for Clark. His accounts receivable for 1918 and 1919 were only a bit over \$3000.<sup>77</sup> He bided his time and quietly turned 50 years old.

## WWJ AND BROADCAST RADIO

Before World War I there was no such thing as broadcast radio in Detroit. In other words, it was generally not possible to sit in front of a radio and listen to news, music or to a ballgame. This all became reality when the radio station that would later be given the call sign WWJ started broadcasting in the summer of 1920. The first plans came about after a meeting on Will Scripps's porch.<sup>78</sup>

Sir Oliver Lodge in England had experimented with high frequency radio nitrifier machines. These machines were supposed to stimulate growth of vegetables and other farm products with radio waves. Clark said that he had read about Lodge's work.<sup>79</sup> A man named McQueery wanted to develop the technology and brought his idea to the Fisher-Johnson Company, who then contacted Clark. Clark built a number of these Lodge high frequency radio nitrifier machines.

Clark's friendship with his boyhood friend Will Scripps, who was an amateur radio operator, had continued. Scripps had a home called Wildwood Farm in Lake Orion. Clark installed one of the radio nitrifier machines at Wildwood Farm. On one of Clark's weekend visits to Wildwood Farm, after dinner, he and

the Scripps family were discussing radio on the porch. The idea of a radio station for the Detroit News was conceived.

At the request of the Scripps, Clark made a presentation to the directors and officers of the Detroit News several weeks later hoping to convince them to build a radio station. Although he thought he hadn't made much of an impression, he was asked several months later to attend a meeting at an architect's office. The Detroit News was designing an addition to their building and the directors had decided to plan for a studio and radio station. Clark then worked out the layout for the radio instruments, studio, and transmitting antenna. Many conferences were held, since nothing like this had ever been done before. Clark was part of a delegation that then went to Washington, D.C., to file for an operating license for the station with the Department of Commerce. The license was granted.

While the construction on the building proceeded and the license application was underway, Clark worked to secure a radio transmitter. He went back to his old company, the General Electric Company in Schenectady, New York, to look over their equipment. He had a good interview and found the equipment he wanted. However, the next day he was told that General Electric Company would not be selling him or anyone else a transmitter for this purpose.

Apparently, the American Telephone & Telegraph Company and Western Electric had advised against it. Clark went to the AT&T office and spoke with several vice presidents hoping to convince them that the venture was reasonable. He was told by one of them

that it was “foolish” to start such an enterprise. Clark was always honest about what he thought about people and he told the vice president in response that he thought he was “dead from the waist up.” Thomas E. Clark didn’t mince words. That was the last time Thomas E. Clark saw any AT&T executives.

The setback was temporary. The company managed to secure its first transmitting station through other channels. The original apparatus consisted of a De Forest Type OT-10 transmitter on the 200 meter wavelength. Under the best conditions, it could be heard about a hundred miles away, with only about 300 receivers in the listening area. Over a ten day period beginning on August 20, 1920, a series of experimental concerts was broadcast. As no public announcement was made, only a few surprised amateurs who happened to be listening in heard the music. The tests were completely successful. It was announced to the public that on Election Day, August 31, 1920, the returns of the local, state and congressional races would be broadcast by means of radio. Two years later, the radio event, called “radiophone,” was described as “fraught with romance.” It certainly was historic. (Fig. 41)<sup>80</sup>

### TECLA OFFERS BROADCAST RECEIVERS

The new industry of broadcast radio exploded onto the scene. In short order, other cities such as Pittsburgh, Pennsylvania, established their own broadcast stations.<sup>81</sup> Clark recognized the wonderful opportunity he had to get in at the ground floor of the new industry. As a result, TECLA produced a whole new line of prod-

ucts targeted at the listening public. As he had done during the boom years of the Clark Wireless Telegraph & Telephone Company, Clark spent long hours at the shop and personally supervised the manufacturing process. (Fig. 42)

Starting in the early 1920’s, Clark manufactured several broadcast receivers marketed under the TECLA name.<sup>82</sup> The smallest was called the TECLA “Ten”. (Fig. 43) He considered the “Ten” to be an “ideal radio phone for people living in or near a city where there is a broadcasting station, making long receiving radius unnecessary.” The “Ten” had a receiving radius that was advertised as about 20 miles, and it sold for ten dollars.



Fig. 41. Lee De Forest seated in front of a De Forest OT-10 radiotelephone. This is the model used for the first experiments in broadcasting at the station that became WWJ. The man standing in the center is Will Scripps and the man in the framed photo at the upper left is his father James Scripps. The photograph was probably taken in the 1950’s. Photo source: Courtesy, History of San Jose.



Fig. 42. Clark in the laboratory testing one of the custom tube receivers about 1922 in photograph taken for the Detroit News. Photo source: TECLA historical archive.

The TECLA “Thirty” (Fig. 44) was a very popular product. The advertised receiving radius was 25 to 35 miles and it was sold with double headphones, an aerial wire, ground wire, and insulators and hooks to raise the antenna. The price for the whole package was \$30, but it could be bought without the headphones or aerial assembly for only \$20. It was en-

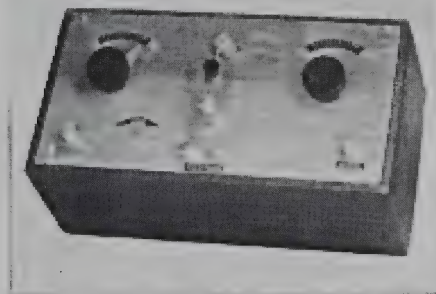


Fig. 43. The TECLA “Ten.” It sold for \$10 and was considered an ideal radio for people living in a big city. Photo source: TECLA historical archive.

closed in a leatherette case with a fold-down lid. This was a good value for the price at the time, although tubes were becoming more available quickly and would soon make the “Ten” and the “Thirty” with their crystal detectors and cat whiskers obsolete.

The “Thirty” was intended to be a portable radio, to be taken on family outings. It was “perfect” for the family trip—“When you go motoring or yachting, pack your **Tecla** and when you stop along the roadside or in your motor boat at the lake, suspend your

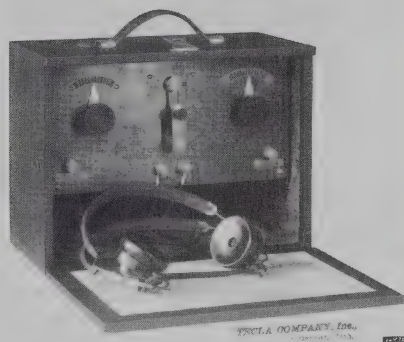


Fig. 44. The TECLA “Thirty.” TECLA’s most popular broadcast receiver. It could be bought complete with headphones, aerial wire, ground wire, insulators and hooks for \$30 or without the accessories for \$20. The crystal detector is in the center. Photo source: TECLA historical archive.

wire between trees, poles, or masts, and run to the aerial post. Run your ground wire into the ground or to the water pipe and “listen in”. Alternatively, you could “Attach an aerial to one side of the car top and put your “Tecla” in the car. While you are eating your lunch by the roadside, enjoy the radio program from your nearest broadcasting station.” One ad cut suggested that the modern businessman should “put on the headphones of your Tecla and get the market reports, sport



news, weather forecasts, etc. clearly and distinctly."

The TECLA "Fifty" was Clark's first commercially advertised receiver that incorporated a tube detector (Fig. 45).<sup>83</sup> The receiving radius was promoted as 150 to 200 miles. Complete with double headphones, B battery, detector

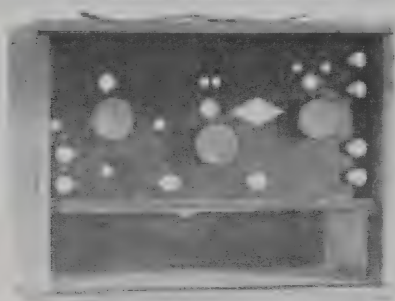


Fig. 45. The TECLA "Fifty." Complete with headphones, B battery, detector bulb, lightning arrestor and aerial assembly for \$65. Photo source: TECLA historical archive.

detector "bulb," lightning arrestor and aerial assembly it sold for \$65 in a leatherette case. Without the separate parts, the basic receiver could be bought for just \$40. The TECLA "Two Stage Amplifier" (Fig. 46) was specifically intended for use with the TECLA "Fifty"

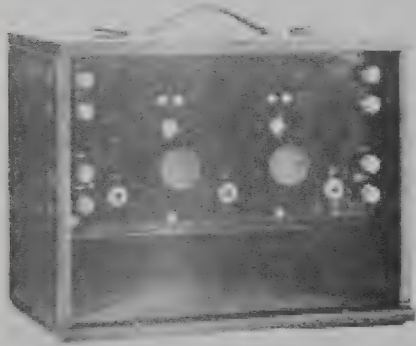


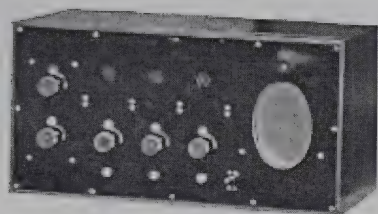
Fig. 46. The TECLA "Two stage amplifier." It was intended for use with the TECLA "Fifty," but could be used with any detector. Photo source: TECLA historical archive.

although it could be used with any detector. The "Two Stage Amplifier" increased the receiving range of the "Fifty" to 800 to 1000 miles. It was built in a leatherette case and sold separately for \$60.

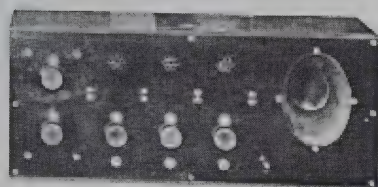
The TECLA "Ten," "Thirty" and "Fifty" receiving sets were built in large numbers at the Cass Street factory. In addition, Clark offered three higher priced receiving sets that were custom built when ordered. These were the Type 250-A, Type 250-B, and the Type 300. (Fig. 47) The Type 250-A and Type 250-B had tube detectors and two-stage amplifiers. They had "loud talkers" (speakers) built into the panel making headphones unnecessary. The Type 300 had tube detector and a four-stage amplifier. A loop antenna and a horn loudspeaker were available as accessories for the Type 300.

The No. 500 Tecla Radio Receiving Unit was specifically manufactured for use on automobiles in motion and was available prior to 1922. It had three stages of radio frequency amplification, three stages of audio frequency amplification, a special tuner for aerial and ground, and a special loop to be used for reception without ground when the automobile was moving. The No. 500 was said to be able to pick up all American and Ship Stations from New York to Los Angeles.

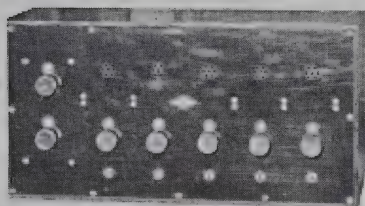
Clark seems not to have favored newspaper advertising and radio magazine advertising as means to market his products. This may have had the dual result of missing a market opportunity, and keeping a low profile when historians of early radio searched in the usual places for evidence of manufacturers. They tended to miss the presence of Tecla.



TYPE 250-A



TYPE 250-B



TYPE 300

Fig. 47. The TECLA Type 250-A, Type 250-B, and Type 300 short wave tuners. These tube containing receivers were built to order. Photo source: TECLA historical archive.

## THE DETROIT RADIO SHOW AND AMERICA'S FIRST RADIO TOUR

TECLA needed to get its brand name into the public eye and participated in two grand promotional opportunities in 1922. One of these was the Detroit Radio Show. (Fig. 48) TECLA's booth at the show was mainly a wonderful historical review of early wireless. There were posters showing the factory and the panel transmitter. Many pieces of early wireless equipment lined the cabi-

net tops and shelves. These included Clark's early school demonstration coherer receiver set, variable capacitors, induction coil spark gap transmitters, a wavemeter (Fig. 49), early receivers with crystal and electrolytic detectors (Fig. 50), a rotary spark gap (Fig. 51), a large quenched spark gap (Fig. 52), and other delightful relics of what must have seemed like a long time past. It had only been a decade or two.

The early radio gear lured the show's visitors up to the TECLA display. Standing in front of the display on a short pedestal was a TECLA "Thirty" with the cabinet open. Two posters set off to the right of the "Thirty" invited visitors to "Listen in on a TECLA *Thirty*." TECLA obviously intended to sell many of these receiving sets at the show. Much of the space behind the cabinets and against the wall was lined with boxes of them, with aerial wire coils displayed in front.

The more sensational event in 1922 gave TECLA national exposure. This was "America's First Radio Tour."<sup>84</sup> The Detroit Board of Commerce, the Detroit Automobile Association and the Lincoln Highway Association sponsored the tour. Two Rickenbacker sedans with advanced motors that minimized vibration were selected for the expedition. (Fig. 53) The cars drove 2,800 miles on a 40 day journey from Detroit to San Francisco between June 1 and July 10, 1922. The entire equipment in the radio car was designed and built by TECLA.

The radio receiver was built into the car and featured a tube detector and several stages of amplification. The radio car was equipped with a 200 foot long loop aerial on top. It also carried a second 200 foot emergency aerial



Fig. 48. The TECLA display in the Lecture room at the Detroit Radio Show in 1922. The TECLA "Thirty" is on the low pedestal in front and in boxes behind the display with aerial wire coiled with them. The remainder of the display is historical equipment made and used by Clark over the two prior decades. Photo source: TECLA historical archive.

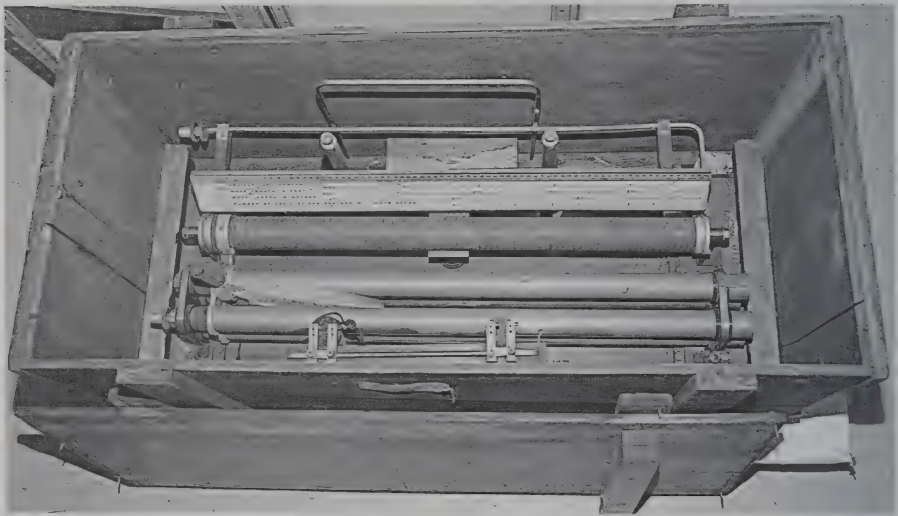


Fig. 49. Wavemeter made by Thomas E. Clark in 1900 and currently at the Detroit Historical Museum. It is behind the TECLA "Thirty" in the photograph of the 1922 Detroit Radio Show. It is 38 inches long. The coil in the back is the inductance and the four tubes in the front serve as variable condensers. Capacity is varied by sliding the tube in or out. The wavemeter is packed in a large wooden crate. Photo source: Dick Clark.



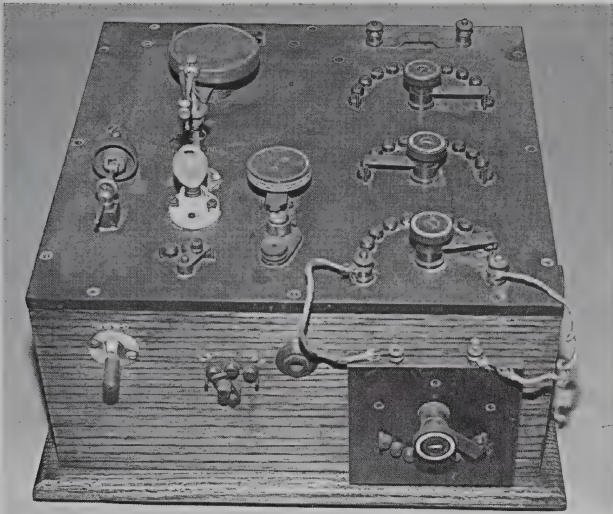


Fig. 50. Early receiver made in 1903 by Thomas E. Clark. It features built in tuning coils, condensers and three different detectors. It has a bornite crystal pressing against a zincite crystal, a sulphuric acid electrolytic detector to which he added a drop of glycerine to make the signal louder, and a silicon crystal. This model was sold to the U.S. Signal Corps and Navy in 1904. It is also easily visible in many of the photos of early Clark commercial stations. This receiver is in the Detroit Historical Museum collection. Photo source: Dick Clark.

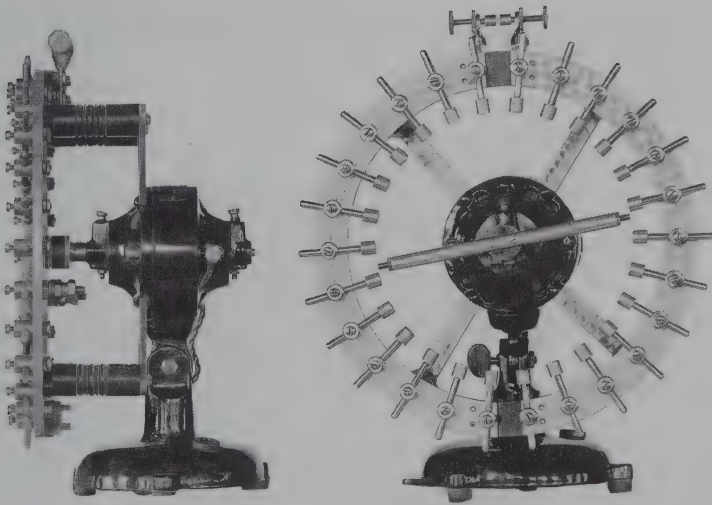


Fig. 51. Large rotary spark gap as seen at the Detroit Radio Show in 1922. It currently resides at the Detroit Historical Museum. This type of rotary gap was made by Clark for both wireless telegraph and wireless train control systems. Photo source: TECLA historical archive.

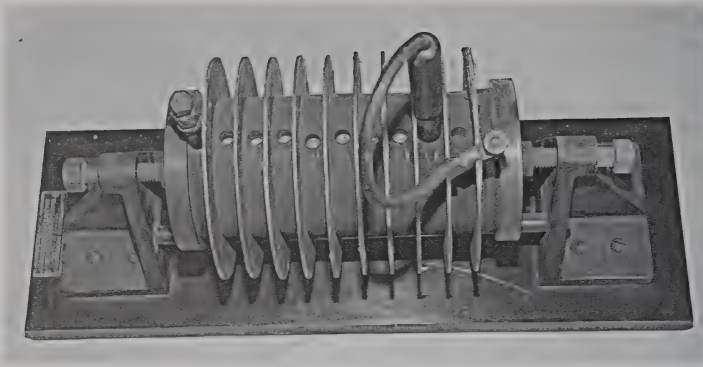


Fig. 52. This large Clark quenched spark gap was on the top shelf at the Detroit Radio Show in 1922 and was donated to the Detroit News and then to the Detroit Historical Society in 1950. The large quenched gaps like this one which weighs about ten pounds made by Clark had a unique pin that fit in a socket between the cooling vanes to choose the number of gaps in the circuit. The smaller gaps had a more conventional clip type connector. Photo source: Dick Clark.

attached to the running board that could be stretched out and attached to a high point at a distance for better reception if nec-

essary. The Magnavox horn loudspeaker mounted on top of the roof played the radio programs for crowds assembled around the sedan.



Fig. 53. This Rickenbacker sedan carried the Clark radio receiver on America's First Radio Tour. The loop antenna can easily be seen on the top of the car along with a loudspeaker. Photo source: TECLA historical archive.



Where possible, the cars stopped at noon and again every evening to give concerts for the onlookers. This was the first time a radio equipped vehicle crossed the continent and thousands of people were exposed to the experience of broadcast radio for the first time. The second car on the road trip was a supply car carrying spare parts for the radio in case they were needed. The radio never had any failure at all though, and only one tube needed to be replaced on the trip.

The publicity was marvelous. Newspapers, especially the San Francisco Chronicle, carried headlines that let people know when the cars were in their city and advertised the event. America's "ace of aces" Eddie Rickenbacker was on hand in Detroit to see the cars off. Clark did not accompany the tour, but se-

lected Detroit businessmen and radio operators Wallace Blood and William Heinz and their wives to be in charge.

There was a Second Radio Tour put on by TECLA within a year or two. This was not as grand an event and the vehicle that was used looked a bit like a converted pickup truck. There was a horn speaker installed on top of the cab.

## GOVERNMENT WORK, AND THEN THE DEPRESSION

TECLA also obtained government contracts for wireless from about 1924 to 1934. These were tube transmitters and receivers. (Fig. 54) They were no longer as bulky and dangerous to operate as the spark transmitters had been. Some of these transmitters and receivers were sold to

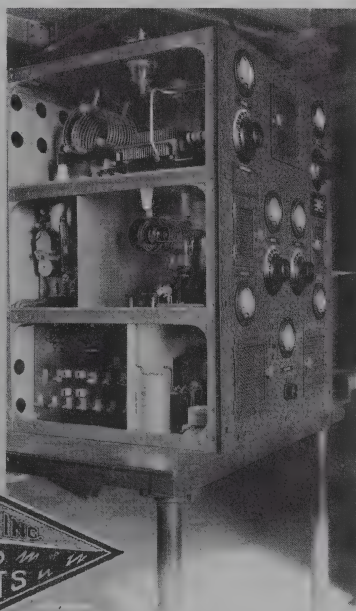
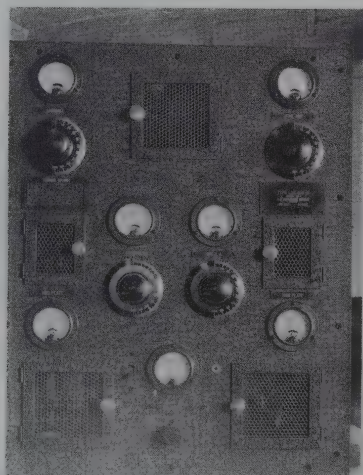


Fig. 54. Radiotelephone Type LSR 305-B made in 1931 for the U.S. Lighthouse Service. Photo source: TECLA historical archive.



the Department of Commerce and were used for communication between aircraft and ground<sup>85</sup> and between Department of Commerce offices in various cities. TECLA also developed radio beacon sets for the Department of Commerce. They were installed on the Great Lakes, New York Harbor near Sandy Hook, and on Puget Sound.

When the Detroit police department became the first to have police cars around 1924, TECLA installed the first experimental radios on them. TECLA sold them much of the equipment for the different police stations. In the game of cat and mouse, Clark said that, "There was a time when everybody used wireless, even the crooks. They gave a bad reputation to the activity."<sup>86</sup>

Clark worked hard on automatic and wireless train control during the 1920's. He expected this more than anything to lift TECLA up a notch in the manufacturing sector. He could not have anticipated the roadblocks he would encounter and the impact that the Depression would have on the company.

Clark was a longtime member of the Institute of Radio Engineers. In 1927 he became the founding Chairman of the Detroit Section of the IRE. This was quite an honor.

## WHAT DO WE DO NOW?

The Depression years were tough for TECLA and the company nearly succumbed to the poor business environment. The manufacture of broadcast receivers had looked promising in the early 1920's, but the competition became very intense as hundreds of brands came on the market and regenerative receivers built under Armstrong's licenses became the

market leader.

The TECLA line of broadcast receivers was improved and placed into cabinets more acceptable to the customer. The model 50D detector panel (Fig. 55), the 50A amplifier, 100DA receiver (Fig. 56), 200DA receiver (Fig. 57), RF200 receiver (Fig. 58), and other models (Fig. 59) made their appearance before the Depression but could not maintain TECLA's market share as companies such as Atwater Kent and many others took over.

Clark, now 60 years old, and his son James who now was more involved in running TECLA, needed to reinvent the company



Fig. 55. TECLA Type 50D detector panel, made in the 1920's. Photo source: TECLA historical archive.

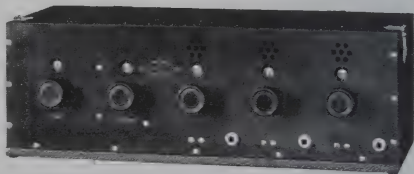


Fig. 56. TECLA Type 100DA receiver made in the 1920's. Photo source: TECLA historical archive.

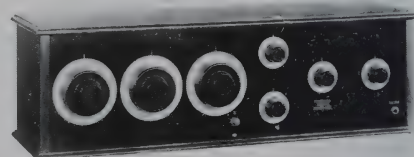


Fig. 57. TECLA Type 200 DA receiver made in the 1920's. Photo source: TECLA historical archive.

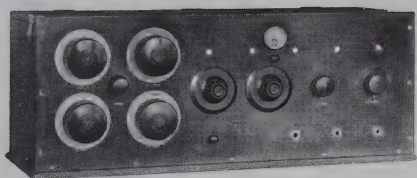


Fig. 58. TECLA Type RF 200 radio receiver, similar to other receivers made by TECLA in the 1920's. Photo source: TECLA historical archive.



Fig. 59. A compact TECLA receiver without an obvious model number made during the 1920's. Photo source: TECLA historical archive.

one more time to stay in business. One of the employees in their machine shop was a marine engineer<sup>87</sup> who had emigrated from Scotland. He was a dog show judge who showed Scottish Terriers as a hobby, and he complained about the poorly suited files that had to be used to trim their toenails. This was the impetus behind the invention and patent of the guillotine type dog nail trim-

mer by TECLA in the 1930s. The idea for the nail trimmer came from a bamboo needle cutter made by Columbia Phonograph.<sup>88</sup> Sales of this unlikely product marketed under the brand name "RESCO" and other pet products revived TECLA's sagging sales and brought it back to profitability. This nail clipper is still for sale.

## WORLD WAR II

Thomas E. Clark went into semi-retirement after seeing his company weather the rough years, and after about 1930 the business was run by his sons James and Norval. His other son, Thomas, died at a rather young age in 1941. Clark began to pay more attention to his private life. Unfortunately, little is known about Clark's wife Agnes Laing. She was good natured and slim in figure. After having gone blind, she died in 1938, possibly from complications of diabetes.<sup>89</sup>

During World War II, TECLA made parts for a number of pieces of equipment that did not bear the manufacturer's label, according to Clark. This equipment went to Dayton, Camp Evans or Watson Laboratory in New Jersey. It consisted of parts for amplifiers and equipment possibly destined for use on radar.<sup>90</sup> TECLA also made parts for aircraft engines during World War II as well as lathe products for munitions and machine parts.<sup>91</sup>

Clark was well-respected and liked by the farmers who owned the farms near the family cottage on Lake Huron. A son of one of the farmers was killed in action in World War II. Clark built an open air log cabin to be used as a picnic pavilion as a memorial to the fallen soldier.<sup>92</sup>

Thomas E. Clark helped support his youngest son Norval

and his wife Jane Clark during Norval's four years in the service. Jane Clark lived in Thomas E. Clark's apartment during for these four years just after the war. When Norval was working at the TECLA plant during the time it was located on Schaeffer Road in Detroit, Thomas E. Clark helped Norval and Jane buy their first house.<sup>93</sup>

From this point onwards the company began to concentrate on the manufacture of mechanical items and the machining of parts rather than electrical supplies. Quite a bit later TECLA moved to Walled Lake, MI, and diversified further. TECLA currently consists of four divisions: fishing accessories as "Bert's Custom Tackle," the pet products as "Resco," TECLA marine, and TECLA industrial. TECLA continues to prosper but has had no further involvement with broadcast radio.

## FULL RETIREMENT AFTER 1950

Clark donated his early radio equipment to the Detroit News in 1950. The Scripps family arranged with him to have the equipment permanently located at the Detroit Historical Museum, where it still can be seen.<sup>94</sup> The equipment is to a great extent the same historical display that Clark presented at the Detroit Radio Show of 1922.

Another interesting event occurred in 1950— Clark visited television station WWJ-TV for the first time just after his 81st birthday. (Fig. 60) The personal tour was led by WWJ-TV engineering director Dick Love.<sup>95</sup>

He continued as a member of the Institute of Radio Engineers into his sixties and associated with the IRE socially even into his eighties. (Fig. 61)

Clark continued to enjoy summers at his cottage at Bruce Beach in Canada near Clark Point. He was an early riser and went to bed early as well. He put his grandchildren to sleep at 8:30PM or so, but unbeknownst to him the boys would loosen the window screens and sneak out to meet girls.<sup>96</sup> He was a kind, honest, and practical sort of man who was at ease discussing current affairs, and also enjoyed telling stories. He never spoke of his own mother and father, or of his brothers, aunts and uncles who also lived in the Detroit area.

Clark was born just a few years after the Civil War, but lived to see transistor radios. The transistor was invented in 1947 and the researchers who worked on it were awarded the Nobel Prize in 1956. Clark was delighted to read about these exciting new developments, but may have been a little chagrined to learn that the investigators worked for his old "friend" AT&T whose executives had tried to discourage him from obtaining a transmitter for WWJ almost 40 years earlier.

The old Clark factory on the northwest corner of Cass and State Streets in downtown Detroit no longer exists. In its place now stands a skyscraper currently occupied by AT&T. A people mover monorail operates just across the street.

Thomas E. Clark died in 1962 at the age of 93, one year after the Detroit Historical Society honored him with a display that traced the history of radio in Detroit. The obituary in the Detroit News read, "T.E. Clark, Early Radio Genius, Dies."

## ACKNOWLEDGEMENTS

This manuscript would certainly not have been possible with-



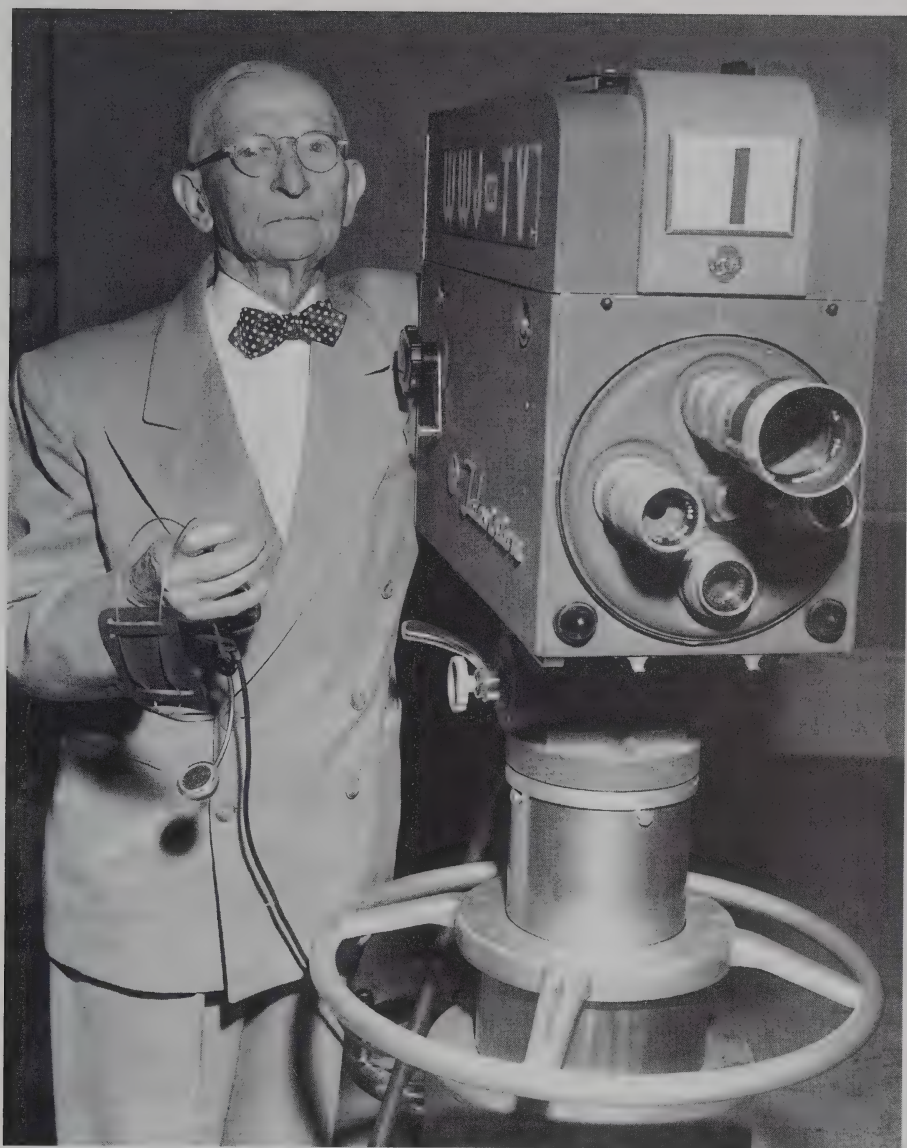


Fig. 60. Thomas E. Clark visits WWJ-TV for the first time in 1950. He is 81 years old at the time of the tour of the television station. Photo source: TECLA historical archive.

out the generous support of the entire Clark family, including Jane Wells Clark, Dick Clark and his wife Donna Caruss, Robb Clark and his wife Judy, Jeff Clark and his wife MaryLou, Jimmy Clark and his wife Jean, and Jean Auchterlonie and her husband George. They provided me with

written and audio documents and allowed me to record their oral histories at a family reunion at the Village Club in Birmingham, Michigan on February 17, 2009.

We are also indebted to David Schneider and the Detroit Historical Society for allowing us access to the Collection Resource



Fig. 61. Thomas E. Clark with Miss IRE (Institute of Radio Engineers) about 1950. Photo source: TECLA historical archive.

Center. The collection that Thomas E. Clark initially donated to the Detroit News is still housed at this facility. We were given permission to photograph Clark's original equipment and scan paper material.

We would also like to thank TECLA Co., Inc. for allowing us an entire week to work through the thousands of pages of photographs, company bulletins, original blueprints, letters, and other documents at the plant in Walled Lake, Michigan.

Many thanks to Christie Edinger for helping me navigate the United States Patent Office website, and to Debbie Spatafora at WWJ Radio in Detroit for her help with the archives there. We are grateful to Jim Reed and History San Jose for letting us use the photo of Lee De Forest in front of the OT-10 transmitter.

## REFERENCE NOTES

- 1 "History and Biography of The City of Detroit and Wayne County, Michigan," published by Henry Taylor & Co., Chicago, IL, 1909. Because Tecumseh was not incorporated at the time, some biographers list Clark's birthplace as Windsor.
- 2 "The Reminiscences of Thomas E. Clark," Oral History Research Office, Radio Unit, the result of an interview with Thomas E. Clark by Frank Ernest Hill on May 24, 1951.
- 3 From a Detroit News newspaper clipping dated only "1907."
- 4 "Emil J. Simon: A Busy Life Indeed," by Russ Kleinman, Karen Blisard, A.J. Link and Warren Berbit, published in "The Antique Wireless Association Review," Vol. 20, 2007.
- 5 From K.L. Nichols, The White City: <http://members.cox.net/academia/cassatt8.html>.
- 6 From oral history taken from Dick Clark, Feb. 17, 2009 by Russ Kleinman.
- 7 Interview with Thomas Clark recorded October 6, 1956. Probably Detroit News but uncertain.
- 8 Due to the plasma effect, named by Irving Langmuir in 1928.
- 9 From notes in Clark's own handwriting scribbled at the fair.
- 10 Clark's transcribed oral reminiscences also mention an "E. Monier" from France. This name does not appear in other wireless references.
- 11 All of the information regarding Froloff and Church are from also from the October 6, 1956 recording.
- 12 Clark's own statement to the Detroit News, 1907.
- 13 From oral history taken from Jimmy and Jean Clark, February 17, 2009 at the Village Club
- 14 From oral history taken from Dick Clark, February 17, 2009 at the Village Club.
- 15 Interestingly, the number 200 comes up most often with regard to the number of sets sold. However, a magnified view of a

- poster at the 1922 Detroit Radio Show clearly states that 1000 were sold.
- 16 Same as 2.
  - 17 Spark signals were broad and would still have interfered with each other to some extent even if separated by some distance in wavelength.
  - 18 Kellogg, R.L., "History of Radio in Michigan," in "The Michigan History Magazine, Winter number, 1937, as quoted in "Wireless Communication in the United States," by Thorn L. Mayes, New England Wireless and Steam Museum, 1989.
  - 19 Same as 2.
  - 20 This was the name given to it by Clark. It was more than likely actually the Detroit Telephone Company.
  - 21 This same story has been retold over and over in books and newspapers with different degrees of embellishment, but this version is probably as close to the truth as any. From The Detroit News Magazine Page, written by George W. Stark, June 6, 1950.
  - 22 Message sent from William C. Maybury, Mayor of Detroit between two Clark Wireless Telegraph Stations in 1901. Facsimile at the Collections Resource Center of the Detroit Historical Museum.
  - 23 All patent information is from the U.S. Patent Office's searchable website.
  - 24 TECLA historical archives, multiple letters from Foote, Pierson & Co. to Thomas E. Clark doing business as the Electric Service & Appliance Co. starting February 20, 1902. This particular letter is the letter quoting the 40% discount for the registers.
  - 25 From the "Blue" prospectus, undated, entitled "Clark Wireless Telegraph-Telephone Systems" and published by Clark Wireless Telegraph-Telephone Company, (Inc.), Detroit, MI.
  - 26 TECLA historical archives, letter from C.F. Splitdorf to Electric Service & Appliance Co., dated February 21, 1902.
  - 27 TECLA historical archives, letter from E. Whitmore of Manhattan Electrical Supply Co. to Electric Service and Appliance Co., dated February 12, 1902.
  - 28 TECLA historical archives, letter from Hodge of Queen & Co., Inc., to Electric Service & Appliance Co., dated January 22, 1902.
  - 29 TECLA historical archives, letter from J.H. Bunnell & Co. to Electric Service & Appliance Co., dated May 21, 1902.
  - 30 TECLA historical archives, letter from Electric Service & Appliance Co. to C.E. Ellis, United Fruit Co., New Orleans, LA, dated May 27, 1902.
  - 31 Article entitled, "The Wireless Specialty Apparatus Company," by Russell Kleinman, in The Old Timer's Bulletin, published by the Antique Wireless Association, May, 2000, Vol. 41 #2.
  - 32 Letter from Lee de Forest to Thomas E. Clark, dated March 5, 1910.
  - 33 Letter from Wichi Torikata to Thomas E. Clark, dated Feb. 7, 1910.
  - 34 Tecla historical archive.
  - 35 The Clark house was at 4104 Avery Avenue. At that time, Avery Avenue was paved with one foot long wooden blocks treated with creosote.
  - 36 Same as 2.
  - 37 Same as 1.
  - 38 In fact, the first NESCO orders for pack sets would not be until 1906 at the earliest. See Kleinman et. al. in "Pack Sets- Spark Hits the Beach," AWA Review No.16, 2003.
  - 39 "Wireless Telegraph and Wireless Telephony," by Charles G. Ashley and Charles B. Hayward, American School of Correspondence, Chicago, 1912.
  - 40 Information on the wagon sets and the portable sets with kite are directly from blueprints in the TECLA historical archive.
  - 41 Information from undated Clark prospectus.
  - 42 In fact, since none of the bulletins



- were dated and the first few were not numbered, it is quite difficult to actually determine the order of the first few bulletins.
- 43 Interestingly, the drawing is copyright 1902, but Clark in later years said that the Bulletin was published in 1904.
- 44 Many bulletins and prospectuses have surfaced, but no material that one would call a catalog. In one bulletin, Clark does mention that changes occurred so quickly that the company intended to communicate them with bulletins rather than other means.
- 45 Spark sets inside explosive situations such as a mine would have been exceedingly dangerous. For mines isolated by terrain, a wireless station might be used at a safe distance from the mine to communicate to a remote location.
- 46 Stark, George W., Chapter XXV The Radio Pioneers, in "Detroit an Industrial Miracle," published 1951.
- 47 TECLA historical archive blueprint.
- 48 From an undated Clark prospectus.
- 49 Clark Wireless Telegraph & Telephone undated blue prospectus.
- 50 In Clark's words.
- 51 "Wireless Telegraph and Telephone," Thomas E. Clark, Association of Engineering Societies, Vol. 11, No.3, March 1908.
- 52 From an undated brochure entitled, "Questions and Answers Regarding the Clark Wireless Telegraph-Telephone Co." in the TECLA historical archive.
- 53 The information about Norval Hawkins is from the oral history given by Dick Clark, February 17, 2009.
- 54 It is unfortunate that Clark did not put a date on his Bulletins or on the prospectuses. This is from a brown covered 8x10" undated prospectus with the title "Wireless Telegraph" on the cover.
- 55 Loose news clippings in the TECLA historical archive without date.
- 56 News clipping, Bay City Tribune, June 20, 1909, front page headline.
- 57 News clippings, Alpena Evening News, June 17, 1909.
- 58 Although he thought de Forest was too self-absorbed.
- 59 "Wireless Communication in the United States," Mayes, Thorn L., The New England Wireless and Steam Museum, 1989, page 100.
- 60 "Empire of the Air, the Men Who Made Radio," Lewis, Tom, Harper, New York, 1993, page 50.
- 61 Same as 44.
- 62 TECLA historical archives, letters from A. Frederick Collins to Thomas E. Clark dated March 28, 1902 and April 4, 1902.
- 63 Same as 2.
- 64 From court documents regarding the case in the TECLA historical archive.
- 65 TECLA historical archive, letter from Clark Wireless Telegraph & Telephone Co. to Phillip McMillan of D&C Navigation Co., dated July 22, 1910 advising him of dismissal of the suit by the court.
- 66 New York Times, November 23, 1910.
- 67 Letter from Major Bullard to Thomas E. Clark, dated June 22, 1910.
- 68 Letter from Lee de Forest to Thomas E. Clark, March 5, 1910. See also note 58.
- 69 Copies in the TECLA historical archives. Many of these foreign patents seem to be from 1913.
- 70 Same as 2.
- 71 Personal communication, David Schneider of the Detroit Historical Museum.
- 72 From the TECLA quenched gap spark transmitter brochure.
- 73 From oral history taken from Jean Clark and George Auchterlonie, February 17, 2009, by Russ Kleinman.
- 74 From oral history taken from Robb Clark, February 18, 2009, by Russ Kleinman.
- 75 From oral history taken from Jimmy and Jean Clark, February

- 17, 2009, by Russ Kleinman.
- 76 An assumption made from the fact that virtually no mention of Thomas E. Clark is made anywhere in the George H. Clark Radioana Collection at the archives of the Behring Center, National Museum of American History of the Smithsonian Museum in Washington, D.C.
- 77 United States Internal Revenue Service, Form 1040A, submitted by Thomas E. Clark, and balance sheets for the years 1918 and 1919.
- 78 Same as 2.
- 79 From 1956 interview.
- 80 "WWJ— The Detroit News," published by that company, Detroit, MI, 1922.
- 81 KDKA— this station also claims to be the first broadcast station programming regularly the United States. They were both on the air within a few months of each other.
- 82 All the information on the TECLA broadcast receivers is from a foldout white TECLA Co., Inc., brochure that is undated but probably printed just after the 1922 Radio Tour.
- 83 Clark had designed a wireless valve detector using Fleming valves in 1908.
- 83 Same as 2.
- 84 Information about the radio tour from the TECLA historical archive, and also the website of the Lincoln Highway National Museum and archives: <http://www.lincoln-highway-museum.org/RadioT/RadioT-Index.html>.
- 85 Aircraft and ground
- 86 Same as 2.
- 87 At the time, this meant that he looked after the engines on a ship. As it turns out, the engineer's last name was "Laing," but he was no relation to Agnes Laing.
- 88 Written communication from Dick Clark.
- 89 This was the consensus of family recollections during the interviews. A minority opinion was that she had glaucoma and died of complications of a goiter.
- 90 Same as 2.
- 91 Same as 11.
- 92 Same as 6.
- 93 From oral history taken from Jane Wells Clark, February 17, 2009, by Russ Kleinman.
- 94 Letter from W.E. Scripps to the Detroit Historical Museum, May 17, 1950, in the collection of the Detroit Historical Museum.
- 95 Letter from Edgar J. (Dick) Love to Thomas E. Clark, dated June 2, 1950.
- 96 Or so the boys thought....this according to Jimmy Clark. They probably took quite a chance doing this since Thomas E. Clark, who was their grandfather, was quite strict about chores and other household rules. The grandchildren were allowed to spend the summers at the cottage with their grandfather. The parents would come up on the weekends.
- 97 TECLA historical archive typed list, undated.

This article was peer-reviewed.

## PHOTO CREDITS

Photos attributed to Dick Clark are copyright Dick Clark 2009.

**Appendix I.** United States Patents by Thomas E. Clark (many with James Clark) up to the Year 1930.

670,536 patented March 26, 1901/filed June 23, 1900 Shield and Reflector for Electric Lights  
741,767 patented October 20, 1903/filed September 10, 1902 Coherer for Wireless Signaling  
805,412 patented November 21, 1905/filed February 17, 1902 System for Wireless Telegraphy  
918,966 patented April 20, 1909/filed August 7, 1901 Lighting Attachment for Showcases  
1,202,362 patented October 24, 1916/filed March 1, 1912 Thermo-Electric Relay  
1,236,543 patented August 14, 1917/filed December 27, 1915 Circuit-Controlling Device  
1,242,144 patented October 9, 1917/filed February 24, 1914 Track Apparatus for Indicating the Movements of Railway Trains  
1,248,663 patented Dec. 4, 1917/filed April 22, 1915 Speed Controlling Mechanism for Block Signal Systems  
1,267,771 patented May 28, 1918/filed April 22, 1915 Block Signal System  
1,292,708 patented January 28, 1919/filed December 22, 1916 Speed-Controller  
1,297,324 patented March 18, 1919/filed May 27, 1916 Electric Contact Device for Railway-Vehicles  
1,331,486 patented February 24, 1920/filed January 8, 1918 Plaiting Machine  
D54832, patented April 13, 1920/filed October 2, 1919 Design for a Combined Electric Fan and Lamp  
1,409,892 patented March 14, 1922/filed February 27, 1918 Loom  
1,478,174 patented December 18, 1923/filed October 25, 1922 Direction Signal for Motor Vehicles  
1,563,075 patented November 24, 1925/filed June 9, 1924 Governor  
1,593,241 patented July 20, 1926/filed November 4, 1925 Process for Tuning Track Currents  
1,619,289 patented March 1, 1927/filed April 6, 1925 Train Control System  
1,619,290 patented March 1, 1927/filed April 16, 1925 Train Control Apparatus  
1,631,361 patented June 7, 1927/filed April 14, 1924 Conductor for Train Control Systems  
1,640,480 patented August 30, 1927/filed June 24, 1925 Air Brake Control Device  
1,646,683 patented October 25, 1927/filed November 21, 1923 Train Control Apparatus  
1,646,685 patented October 25, 1927/filed December 12, 1925 Continuous Train Control System  
1,652,392 patented December 13, 1927/filed November 16, 1925 Humidifier  
1,655,220 patented January 3, 1928/filed May 2, 1925 Three-Position Relay  
1,655,221 patented January 3, 1928/filed February 25, 1926 Track Installation and Train Control Systems  
1,685,479 patented September 25, 1928/filed October 24, 1925 Train Control Apparatus



1,685,480 patented September 25, 1928/filed March 25, 1927 Safety Installation for Grade Crossings  
 1,687,544 patented October 16, 1928/filed November 16, 1925 Electric Fan and Heater  
 1,694,373 patented December 11, 1928/filed November 15, 1926 Train Control System  
 1,697,949 patented January 8, 1929/filed December 13, 1926 Locomotive Control Installation  
 1,702,764 patented February 19, 1929/filed May 20, 1925 Train Control System  
 1,706,022 patented March 19, 1929/filed January 3, 1927 Control System for Railway Trains  
 1,712,788 patented May 14, 1929/filed June 12, 1925 Train Control System  
 1,712,981 patented May 14, 1929/filed December 5, 1925 Railway Train Control System  
 1,718,527 patented June 25, 1929/filed July 17, 1925 Train Control System  
 1,718,528 patented July 25, 1929/filed November 7, 1925 Combined Vacuum Tube and Relay  
 1,737,750 patented December 3, 1929/filed October 23, 1925 Oscillating Circuit for Train Control Systems  
 1,737,751 patented December 3, 1929/filed May 2, 1927 Locomotive Control Installation  
 1,770,371 patented July 8, 1930/filed March 15, 1926 Train Control System  
 1,774,227 patented August 26, 1930/filed July 30, 1926 Locomotive Control Installation  
 1,780,416 patented November 4, 1930/filed May 20, 1927 Track Installation to Control Railway Trains

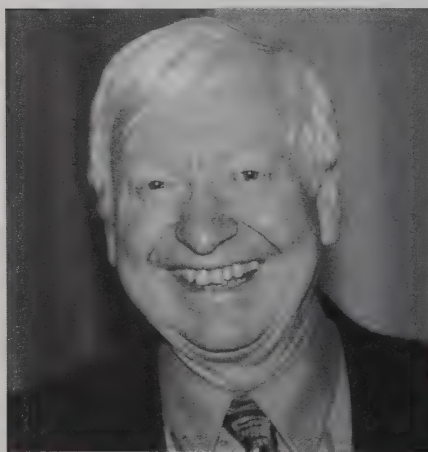
**Appendix II.** Call Letters, Wavelength of Operation, and Power for Clark Wireless Telegraph & Telephone Stations for which the information is known.<sup>97</sup>

Chicago	CG	1900 meters	7-1/2 kW (Continental Station)
Milwaukee	CM	1000 meters	7-1/2 kW (Clark Stations)
Buffalo	CB	1900 meters	15 kW
Cleveland	CN	2000 meters	10 kW
Detroit	CW	1750 meters	5 kW
Pt. Huron	CH	1850 meters	10 kW
Bay City	CY	1750 meters	5 kW
Ashtabula	CO	1500 meters	5 kW
Erie	CI	Not known	5 kW
St. Thomas	CST	1400 meters	5 kW
Duluth	CD	1900 meters	7-1/2
Marquette	CQ	1900 meters	7-1/2
Sault St. Marie	CJ	1000 meters	15 kW (25 kW later)
Saginaw	CAN	500 meters	5 kW
Detroit Lab.	?	variable	variable
Toledo	CT	unknown	5 kW

Most ship stations were 3 kW stations on 500 meters, with a few on 300 meters.

## ABOUT THE AUTHORS

**Dick Clark** the president of Tecla Co. Inc. is a third generation Clark. He is the son of Norval Clark, T.E. Clark's youngest son. He holds a number of patents for improvements to nail trimmers, marine seating inventions, and a Radio Frequency keyless entry system for boat companion way door systems. He has a deep interest in all branches of science and travels extensively. He has a minor in journalism, does science writing and photography. He belongs to a number of technical societies. The Society of Manufacturing Engineers, the Society of Plastic Engineers, and the Engineering Society of Detroit. He is on the technical board of the American Boat and Yacht Council and several committees that write the standards for the marine industry and the U.S. Coast Guard. He is completing his class work to be a Coast Guard licensed charter boat captain.



**Karen Blisard** was born and raised in Lubbock, TX, where she attended Texas Tech University as an undergraduate. She received both her PhD in Pharmacology and her MD from Case Western Reserve University in Cleveland. She did her residency in Pathology and fellowship in Neuropathology at the University of New Mexico in Albuquerque. She was on the faculty at the University of Cincinnati Medical Center before returning to New Mexico to go into private practice in pathology.

Karen (**N5IMW**) was first licensed in 1984, and got her extra class license in 1986. She concentrates on CW and DX, and has enjoyed operating as DX. Her other hobbies include dog sports (agility and obedience), gem cutting and bird watching; she helps with financial support of Russ's telegraph key addiction and is an excellent key-spotter.

Russ and Karen have been married for 20+ years and live in beautiful southwest New Mexico. Their home at 6700 feet at the edge of the Gila National Forest is shared with three shelties and various wild birds, including hummingbirds in season.



**Russ Kleinman** was born in Cleveland, Ohio, but grew up in southern California. He attended Stanford University as an undergraduate, and Case Western Reserve University in Cleveland for medical school. He did his residency in General Surgery at the University of New Mexico in Albuquerque. After a few years in Cincinnati as a general surgeon he returned to New Mexico.

Russ, **WA5Y**, received his first amateur radio license in 1970 at the age of 15. He has been active in many phases of the hobby, but CW has always been a major interest. His current interests include DX and CW contesting but his major passion is the history of telegraphy. He has spent the last several years pursuing information on early wireless history.







## AWA Review

## Mental Radio: Wireless and Telepathy

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**ABSTRACT**

A number of recent studies have been undertaken into the historical relationship between the development of radio, psychic research and telepathy<sup>1</sup>. However there has been little focus on a series of broadcast mass telepathy experiments that took place throughout the world in the 1920s and 1930s at the beginning of the broadcast era. This paper initially explores the nineteenth century thinking that underpinned the creation of a linkage between what are now considered disparate sciences and introduces some of the key scientific minds who drove those ideas. From this point we can trace how these ideas entered into popular culture in the early twentieth century and culminated in a series of broadcast telepathy tests which both enthralled and entertained early radio audiences. Whilst the validity of telepathy was never proven through these tests the power of broadcasting to promote and popularise the idea of telepathy with a mass audience is clearly evident.

**THE ORIGINS OF PSYCHIC RESEARCH, TELEPATHY AND WIRELESS**

In order to understand how a relationship developed between radio, telepathy and psychic research in the twentieth century it is necessary to cast back to the emergence of a range of new sciences and technologies in the mid nineteenth century<sup>2</sup>. Of particular importance was the initial emergence of the telegraph and subsequent broader thinking on the electromagnetic spectrum culminating in the invention of wireless telegraphy.

The starting point for convergence of ideas about telegraphy and spiritualism is often cited very specifically as taking place in the small village of Hydesville, New York southeast of Rochester on 31<sup>st</sup> March 1848.<sup>3</sup> The Fox family had been regularly kept awake by a series of unexplained disturbances in their home for several months. That night the rapping sounds became both persistent and violent. Late in the evening Kate Fox, the youngest daughter in the family, used hand claps to 'communicate' with the rapping or knocking sounds. Soon her older sister joined in and the mysterious 'spirit' was able to respond to questions put by the girls' mother using a rapping code(see Fig. 1).

Taking place just ten years after Samuel Morse's remarkable invention of the telegraph the case of the Fox sisters caused a sensation and triggered a world wide wave of interest in spiritualism.<sup>4</sup> The supposed method of spiritual 'communication' had clear links with the telegraph.



Fig. 1. The Fox Sisters

Whilst the Fox sisters 'communications' were eventually shown to be simply the cracking of their toe joints, public interest in spiritualism quickly spread throughout the United States and to the United Kingdom.

The proof or otherwise of spiritualist phenomena attracted not only the interest of ordinary people but increasingly drew the attention of some of the greatest scientific minds of the age. In 1853 Michael Faraday took great pleasure in experimentally disproving the 'table turners' by proposing that the movements of a table at a spiritualist session were due to the unconscious muscle action of the sitters and in the same year the sceptical undergraduate James Clerk Maxwell was also exposed to psychic phenomena.<sup>5</sup>

In the United Kingdom a concerted effort was made to bring greater scientific discipline to psychic and spiritualist research at Cambridge University in 1874 and culminated in the foundation of the Society for Psychical Research (hereafter SPR) in 1882 under the stewardship of some of the leading thinkers of the day including Lord Rayleigh, Oliver Lodge and J.J. Thomson.<sup>6</sup> Lodge in particular was to remain a dominant figure in psychical research for almost the next fifty years.

Critical to establishing a scientific basis to all psychical research, including telepathy, was the need to identify an appropriate analogy to attempt to explain such phenomena. The SPR brought academic rigour to this research and concentrated on developing theories of such phenomena based on new technologies such as the telegraph, the telephone, X-rays and later wireless telegraphy itself.<sup>7</sup> In summarising the simultaneous rise of spiritualism and the devel-

opment of new communications technologies in the late nineteenth century one historian has proposed that the "quest for a hidden pattern, a unifying framework, a fundamental theory, to bring every diverse particle and force in the cosmos was intrinsically the same, whether one stressed the links between, electricity, magnetism, and light, or looked for connections between mind, spirit, and matter."<sup>8</sup>

The analogy with the telegraph had distinct limitations as the telegraph relied on the use of physical networks to transmit messages.<sup>9</sup> However one potential idea was to utilise analogous thinking about the ether which had existed since the time of Newton and upon which Maxwell's electromagnetic theory relied upon for its existence.<sup>10</sup> After all new forms of electromagnetic radiation were being discovered regularly throughout the late nineteenth century including electrical induction, X-rays, black light, radio waves and radio-activity.

Frederic Myers, a founding member of the SPR in the United Kingdom, was the man who had coined the word 'telepathy' in 1882.<sup>11</sup> Myers defined telepathy as the "communication of any impressions of any kind from one mind to another, independently of the recognised channels of sense"<sup>12</sup> and subsequently went on to develop a detailed explanation of how telepathy worked through what he called the 'subliminal consciousness', which relied on the metaphor of the spectrum drawn from the physical sciences.<sup>13</sup> Under this model Myers proposed that the spectrum of consciousness extended 'down' to the physiological functions and 'up' to the possibilities of clairvoyance and telepathy.<sup>14</sup>



The SPRs 'First Report on Thought-Reading' (1882-3), attempted to place telepathy in the context of other forms of known energy transmission:

"It is quite open to surmise some sort of analogy to the familiar phenomena of the transmission and reception of vibratory energy ... One tuning-fork or string in unison with another will communicate its impulses through the medium of the air ... A permanent magnet brought into a room will throw any surrounding iron into a condition similar to its own; and here the medium of communication is unknown though the fact is undisputed. Similarly we may conceive ... that for every thought there is a corresponding motion of the particles of the brain, and that this vibration of molecules of brain-stuff may be communicated to an intervening medium, and so pass under certain circumstances from one brain to another, with a corresponding simultaneity of impressions."<sup>15</sup>

It was a young Oliver Lodge, then lecturing at Liverpool University, who was amongst the first to postulate how the mechanism for telepathy (or thought-transference) may have taken place. Lodge had been exposed to alleged thought-transference amongst shop girls in Liverpool who were repeating the experiments of a travelling 'mind reading' act seen at a local theatre.<sup>16</sup> In 1884 Lodge went on to speculate that:

"...just as the energy of an electric charge, though apparently on the conductor, is not on the conductor, but in all the space around it ... so it may be that the sensory consciousness of a person, though apparently located in the brain, may also be conceived of as also existing like a faint echo in space, or in other brains".<sup>17</sup>

Hertz's experiments in 1888 proving the existence of electromagnetic waves gave added impetus to telepathic research.<sup>18</sup> In 1892 Professor Edwin J. Houston presented a paper to the Franklin Institute in the United States on the subject of 'Cerebral Radiation'.<sup>19</sup> Drawing on Hertz's recent proof of the ability of electrical oscillations in one circuit to create resonance in a distant circuit, Houston proposed a theory that thought waves could travel through the ether and create sympathetic vibrations in a receiving brain.

Following Marconi's achievements with wireless in 1896, Sir William Crookes was one of the first scientists in the United Kingdom to develop a detailed analogy between wireless telegraphy and telepathy. Crookes outlined his ideas in two Presidential addresses. The first was to the SPR (1897)<sup>20</sup> whilst the second was to the British Association for the Advancement of Science (1898).<sup>21</sup> In summary Crookes proposed that the structure of the human brain with its narrow gaps between nerve cells found an analogy in the coherer, which was the device used to detect Hertzian waves in wireless telegraphy.<sup>22</sup> Crookes' views were to drive thinking about the relationship between wireless and telepathy for the next thirty years.

## WIRELESS AND TELEPATHY IN POPULAR CULTURE

If ideas about telepathy were to have remained the province of nineteenth century Cambridge academics debating out the finer points of definition through the pages of the *Journal of the SPR* we would have known little about it today. However these ideas

about telepathy and wireless quickly found there way into popular culture through contemporary writers, songs and music, art and in the theatre hall at the end of the nineteenth and in the early twentieth centuries.

In 1884 Samuel Clemens (Mark Twain) wrote to the editor of the *Journal of the SPR* supporting the continuing experiments in thought transference:

"Dear Sir, I should be very glad indeed to be made a Member of the Society for Psychical Research; for Thought-transference, as you call it, or mental telegraphy as I have been in the habit of calling it, has been a very strong interest with me for the past nine or ten years. I have grown so accustomed to considering that all my powerful impulses come to me from somebody else, that I often feel like a mere amanuensis when I sit down to write a letter under the coercion of a strong impulse: I consider that the other person is supplying the thoughts to me, and that I am merely writing from dictation."<sup>23</sup>

Twain went on to elaborate on these ideas in a short piece in *Harper's Magazine* (1891) entitled 'Mental Telegraphy' which had been first conceived and written in 1878 for *A Tramp Abroad* (1880) but never published. Twain had initially excluded the manuscript on the basis that he "feared that the public would treat the thing as a joke and throw it aside, whereas I was earnest".<sup>24</sup> 'Mental Telegraphy' was Twain's contemplation on the nature of original thought and listed a range of personal experiences where either he or

another person had pre-empted a thought or idea. Ever practical Twain went on to consider mental telegraphy could eventually replace the conventional land telegraph. In 1895 he returned to the subject in 'Mental Telegraphy Again'.<sup>25</sup>

The English novelist Rudyard Kipling took a further step when he published the fictional piece 'Wireless' in *Scribner's Magazine* (1902)<sup>26</sup> which directly explored the relationship between psychic communication and wireless telegraphy. Kipling was no stranger to psychic research, with his sister Alice Kipling actively involved in the SPR and in later recording messages from Frederic Myers after his death in 1900.<sup>27</sup> The genesis of 'Wireless' was a lunch conversation Rudyard Kipling shared with Marconi in 1899.<sup>28</sup> (see Fig. 2) As Kipling explained:

"I got Marconi to talk about wireless, and at the end of an hour I felt that I knew as much about



Figure 2 - Kipling's Wireless

wireless as it was possible for a layman to learn. During the talk I consciously or unconsciously was gathering much material for my story, "Wireless", in which I carried the idea of etheric vibrations into the possibilities of thought transference".<sup>29</sup>

Modernist literature and art in the early twentieth century was influenced by the idea of a connection between thought transference and wireless. In April 1912 the English poet Ezra Pound used a wireless telegraphy analogy when he spoke of the role of the modernist writer literally being the "antennae of the race."<sup>30</sup> Similarly in 1912 the artist Kupka wrote a treatise which positioned the artist as an emitter of telepathic waves which were transmitted by a work of art into the mind of the viewer.<sup>31</sup> DuChamp's *Large Glass*, which was created between 1915 and 1923, makes strong allusions to the emerging technology of wireless telegraphy.<sup>32</sup>

In 1909 the radical journalist and committed spiritualist William T. Stead wrote a piece for the *Fortnightly Review* entitled 'How I know that the Dead Return : A Record of Personal Experience' in which a detailed analogy was drawn between transatlantic wireless telegraphy communications and spiritual 'Marconigrams' being sent from the new world to 'the other side'. Stead's premise was that the "recent applications of electricity in wireless telegraphy and wireless telephony, while proving nothing in themselves as to the nature of permanence of personality, are valuable as enabling us to illustrate the difficulties as well as the possibilities of proving the existence of life after death."<sup>33</sup> In a case of life imitating art Stead went on to drown

in the Titanic disaster of April 1912 and the spiritualist Lady Archibald Campbell claimed "At the first news which had arrived by 'wireless' of the catastrophe, with no detail as to lost or saved, all we who believe in the wireless telephony of the soul put our faith to the test. My request was answered – 'W.T. Stead drowned'."<sup>34</sup>

Other spiritualists and mediums exploited any connection with the emerging technology of wireless even if the link was tenuous. For example, Eva Henderson produced the strangely titled *Wireless Messages from Other Worlds* (1915) which described the spiritualist's communications with creatures from Mars, Neptune, Jupiter, Mercury and Saturn.<sup>35</sup> Apart from the initial reference to wireless in the title nothing else about the topic appears in the text of the book. Even the British writer Sir Arthur Conan Doyle, the creator of Sherlock Holmes the master of logic, threw his weight behind spiritualism with the publication of his *The New Revelation* (1918).

In popular music telepathy and wireless again met. The notion of the disembodied voice had emerged in the 1890s with the gramophone record and this had led to various spiritualist associations, particularly in relation to the voices of the departed.<sup>36</sup> These ideas continued during the early years of the wireless telegraph. The sheet music of popular songs of the early 1900s refer to the emergence of wireless telegraphy and frequently link its almost telepathic qualities with the ability to communicate with separated loved ones both physically and emotionally. Some examples are *The Wireless Man* (1909), *There's a Wireless Station Down in My Heart* (1913) and *There's a Mes-*



sage of *Love in Your Eyes* (1915), whilst the First World War produced songs linking wireless telephony to communication with separated loved ones in *When the Moon is Shining Somewhere in France* (1917) and *Hello America Hello* (1917). (see Figs. 3-5). The chorus of *Send Me a Kiss by Wireless* (1910) typifies the relationship:

“Send me a kiss by wireless,  
Send me a spark of love.  
Through the air waves that are  
tireless,  
A message from cupid above.  
Send me a flash of spoon-time,  
By wings that are ever true.  
Send me a kiss by wireless,  
And I’ll send it back to you.”<sup>37</sup>

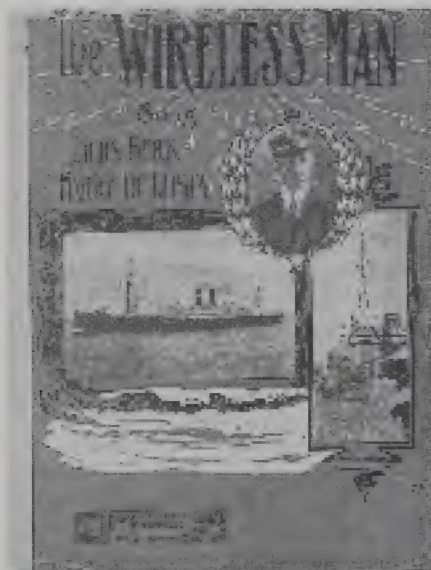


Fig. 3. The Wireless Man (1909)

On the stage there is evidence of wireless telegraphy being incorporated into mind-reading acts in popular theatre. At the St George’s Hall, operated by the Maskelyne family in London, a telepathy illusion known as *The Yogi’s Star* using wireless telegraphy was ini-

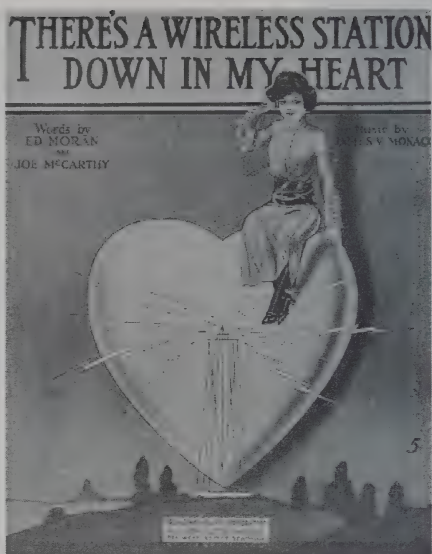


Fig. 4. There’s a Wireless Station Down in My Heart (1913)

tially suggested in May 1911 and first performed in October 1913.<sup>38</sup> In reviewing these early stage acts in *Ray Controlled Mechanism* twenty years later in 1933 Raymond Phillips explained why such tricks had an impact when



Fig. 5 Hello America Hello (1917).





Fig. 7. I Wish there was a Wireless to Heaven

Lodge's close association with the development of wireless telegraphy was well known in the United States and boosted interest in the possibilities of radio being used in conjunction with experimental telepathy. Although as late as 1919 Lodge remained cautious about the alleged relationship, stating that "There is no evidence in favour of such a proposition, and the analogy between telepathy and wireless telegraphy is merely popular and superficial."<sup>46</sup> Conan Doyle was more forthright in his public statements and in May 1922 addressed the American Psychical Institute and Laboratory in New York in the following terms:

"I expect in the next three or four years some definite messages will be received to prove the contentions of the spiritualists. I believe it will come through radio. I think it is along this line that we will get our evidence. They have transmitters in the line of ether,

all we have to have is the receiver."<sup>47</sup>

The *New York Times* sensationally reported the event with the headline 'Doyle Says Ghosts May Use the Radio'.

Perhaps in response to Conan Doyle the then president of the Society of American Magicians, Harry Houdini, published *Ghosts that Talk – by Radio* in October 1922.<sup>48</sup> Conan Doyle and Houdini had first met in England in 1920 and initially established a firm friendship.<sup>49</sup> (see Fig. 8) However the relationship somewhat cooled during Conan Doyle's tour of the United States after the two men disagreed over the outcome of a séance in Atlantic City which purported to make contact with Houdini's mother.<sup>50</sup>

In his article in *Popular Radio* Houdini makes it clear what his views are on spiritualism and psychics and positions himself relative to both Lodge and Conan Doyle:

"There is not the slightest doubt in my mind that such men as Sir



Fig. 8. Houdini and Conan Doyle



Oliver Lodge and Sir Conan Doyle are sincere in their beliefs. They regard spiritualism as a religion; to them it is something sacred. They think the evidence they have obtained is sufficient evidence to justify their faith in their “communications” with those who have passed beyond. I respect them for their sincerity. But I do not share their beliefs”.<sup>51</sup>

However as a matter of ‘public duty’ Houdini systematically explained how inductive methods of wireless (what he called ‘radio telephone’) had been used for several years by magicians, psychics and professional mediums. Houdini went on to describe in detail the radio induction principles of the Trumpet of the spiritualist mediums (Fig. 9), how a “Spirit” listens and speaks (Fig. 10), the Talking Kettle (Fig. 11), the communion of ‘Spirits’ (Fig. 12) and the Talking Buddha (Fig. 13).

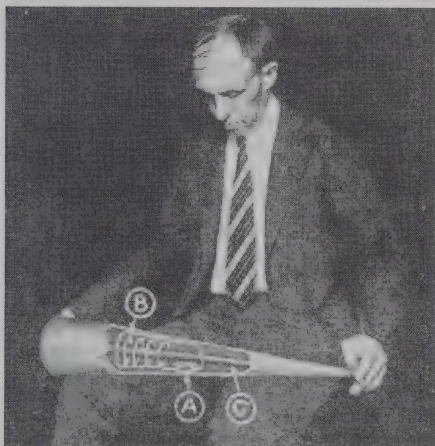


Fig. 9. A trumpet of a spiritualist medium containing (A) a telephone receiver and (B) a receiving coil with (C) the orifice through which the voice was issued.

Whilst this debate about radio and contacting the dead was being fought out in the popular press<sup>52</sup> the laboratory based re-



Fig. 10. Houdini with a microphone and receiver usually used to receive messages in another room by a confederate of the medium.



Fig. 11. Figure 11 Houdini and the ‘Talking Kettle’. The receiving coil was hidden in the false sides of a paper mache kettle with a telephone receiver in the spout.

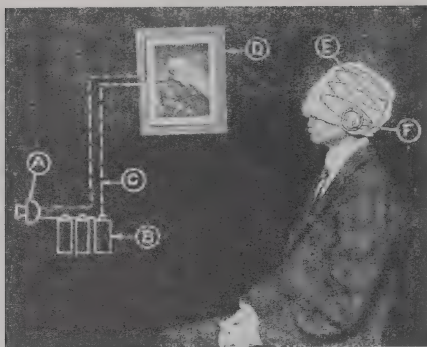


Fig. 12. Another inductive radio trick. (A) is a microphone concealed in another room; (B) is the current supplying current to concealed wires (C); (D) is the picture with (E) the receiving coil that is connected to (F) the telephone receiver over the medium's ears.

searchers were considering how radio broadcasting could be used in telepathy experimentation with the living.

The American SPR had for some time established and supported the Hodgson Fellowship in psychical research, which was tenable at Harvard University. For the academic years 1922-3 it was agreed to augment the funding of



Fig. 13. Houdini demonstrating a variant of an inductive radio trick in which a telephone receiver is concealed in the image's head.

the Fellowship by \$3,000 on the condition that the American SPR, not Harvard University, publish any research findings. Dr Gardner Murphy, a psychologist at Columbia University, was appointed as the Hodgson Research Fellow under Professor William McDougall and retained the post until 1925.<sup>53</sup> During this time Gardner Murphy spent about half his time investigating telepathy.

Dr Gardner Murphy was instrumental in conducting the first verifiable test of mass telepathy through the use of radio broadcasting. According to Gardner Murphy the experiment took place on 2 March 1924<sup>54</sup> in Chicago at station WJAZ, which at the time was owned by the Zenith Corporation and run by Eugene McDonald who took a strong interest in telepathy.<sup>55</sup> He was assisted by Professors Gault and English and a group of 40 'senders' who were concentrating on the test items. The experiment took the form of seven tests of telepathy which were:

1. A number between 1 and 1,000
2. A wild animal with a letter drawn over its head
3. A coloured line drawn to intersect a given black line, colour and angle to be guessed
4. A taste
5. A pain at some point on the hands or arms
6. A drowning man
7. A fireman rescuing a girl.

The experiment resulted in over 2,500 mailed responses. However Gardner Murphy concluded that "the results are a little worse than chance would lead us to expect".<sup>56</sup>

In December 1922 the magazine *Scientific American* had announced a competition to deter-



mine the validity of psychic phenomena and offered \$5,000 prize money. A committee was established to oversee claims and included the likes of Houdini and the psychic researcher Hereward Carrington.<sup>57</sup> Under the *Scientific American* associate editor J. Malcolm Bird the magazine conducted its own radio telepathy experiment in 1924, after the Zenith test, on station WOR. This station was licensed in Newark, New Jersey and had maintained a studio in Manhattan since June 1923. Dr Gardner Murphy was consulted in the experiment.

The results of these tests were reported in the June 1924 edition of the *Scientific American*.<sup>58</sup> This test used four “senders” and the tests were:

1. A number between 1 and 1,000
2. Select one of the 48 U.S. States
3. Name the New York newspaper and store contained in an advertisement
4. Time randomly recorded on a watch face
5. Reproduction of four stick figure and action poses (man waving a flag, running, standing on his head and kicking a football)
6. Identification of an object held in Bird’s hand
7. Trade name from an advertisement in a Sunday newspaper
8. Picture of a sporting event.

In this test 480 responses were received by mail. Most discussion was on Test 5 where 11 complete successes were recorded, 4 of which were in correct order. No less than 100 respondents drew a man running, 25 drew a man standing on his head, and 25 drew the kicking man. Bird concluded

that the scores for Test 5. appeared to be high.

On 19 November 1924 Hereward Carrington appears to have either conducted an experiment or given a talk on telepathy on WAHG, Richmond Hill, New York between 8.50 and 9.00p.m., although no record of the outcome of any test seems to exist.<sup>59</sup>

In Italy research on radio telepathy was taking a different direction. Professor Ferdinand Cazzamali of the University of Milan published a series of papers in 1925 claiming the detection of telepathic ‘brain waves’.<sup>60</sup> Cazzamali placed his subjects in an iron lined room which filtered outside electromagnetic interference and placed a radio receiving set on one side of the room capable of picking up short waves. The subject was worked up into an emotional state and it was claimed that the instrument registered increasingly powerful radiations. He later recorded the impact of these ‘brain waves’ on photographic plates. These experiments served to reinforce the belief that telepathy was a form of electromagnetic phenomena. Such claims were enough for the radio pioneer Hugo Gernsback to write a column in *Radio News* in May 1925 debunking claims about people receiving radio signals in their heads, an affliction upon which he received 10 to 15 letters a week.<sup>61</sup> Russian experiments on electromagnetic waves allegedly produced by both humans and animals were also reported by the popular press in early 1926.<sup>62</sup>

Back in the United Kingdom there had been activity in promoting a radio telepathy test since about June 1924.<sup>63</sup> At that time Harry Price<sup>64</sup>, a psychic researcher, had written to the British Broadcasting Company (here-



after BBC) proposing to conduct a broadcast experiment in telepathy. The BBC rejected this initial proposal on the basis "the Company would be exposed to a deal of criticism, some of which might be quite justifiable".<sup>65</sup> However in 1927 the SPR put forward a similar proposal to the BBC which was this time accepted and scheduled for 16 February 1927 between 11.15 and 11.45p.m. This experiment was carried out by Dr V.J. Woolley and Mr S.G. Soal from the SPR along with six other 'agents' At five minute intervals Dr Woolley produced the following objects:

1. A two of clubs playing card, printed in green on a black background
2. A Japanese print of a skull (in a garden), upon which a bird was perched (Fig. 14)
3. Three sprays of white lilac in bloom

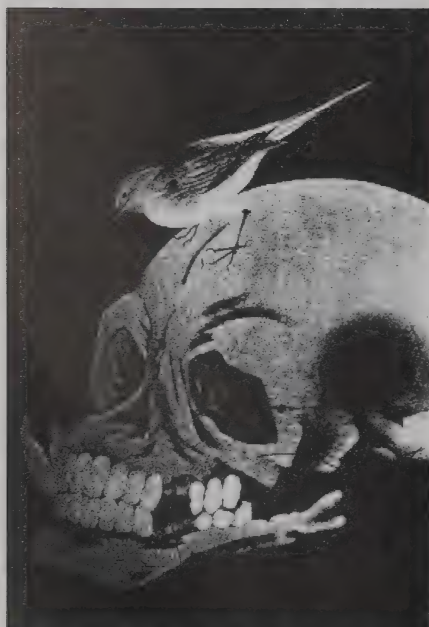


Fig. 14. BBC Test Object

4. Nine of hearts, printed in red on a black background

5. Woolley himself in a bowler hat and mask.

Sir Oliver Lodge was also present on the evening, acting as an announcer, and he asked listeners to "Think in, instead of listen in".<sup>66</sup> The response to the BBC broadcast was remarkable. In all 24,659 listeners responded in writing with 'impressions' to the radio telepathy experiment resulting in 123,295 individual responses.<sup>67</sup> This represented a response ten times that of any other radio telepathy experiment to date. Dr Woolley and Mr Soal of the SPR were responsible for the collation of the results which took some time to complete and contributed to a general sense of anticipation prior to the final outcome being made public.<sup>68</sup>

However despite the significant listener response the experiment gained it is doubtful as to whether the tests used on the night demonstrated any evidence of telepathic communication. In card Test 1 the 2 of Clubs was the correct answer and recorded 190 correct answers from listeners. In card Test 4, the 9 of Hearts was correct and recorded 150 answers. In Test 2, only 5 listeners identified "a skull". In Test 3, only 3 listeners named a white lilac with another identifying a mauve lilac. In Test 5, only 5 listeners identified Woolley as the subject.

Whilst the ultimate result of the BBC radio telepathy experiment was inconclusive it gained significant coverage. Sir Oliver Lodge's presence at the experiment was important and his comments on the outcome of the test were keenly sought by the popular press. At first Lodge was reticent to preempt the analysis of the listener

responses, preferring to await the outcome of the collation of results. However by May 1927 he was prepared to say that the “experiment ...demonstrates that telepathy is not commonly broadcast.”<sup>69</sup>

Dr Woolley reinforced these comments about radio when he said:

“Although wireless was indispensable to its conduct on so large a scale, the part wireless played in the experiment was a purely mechanical one. It merely synchronised the attempts at thought-reception by 2,000,000 minds.”<sup>70</sup>

Read together it is reasonable to infer from these comments that both Sir Oliver Lodge and Dr Woolley were distancing themselves from the electromagnetic theory of telepathy promoted by Professor Cazzamali and his supporters.

The overwhelming public response to the British radio telepathy test triggered further similar experiments in other parts of the world over the coming months modelled on the BBC approach. In early July 1927 radio station 3LO in Melbourne Australia announced that it would be conducting a radio telepathy experiment later that month.<sup>71</sup> Like the BBC experiment the Australian test attracted a large number of listener responses, in this case totalling 15,221 written replies. A panel of three ‘senders’ in the radio studio were asked by an announcer to think about a series of objects as they were drawn out of sealed envelopes. These objects were:

1. A penny
2. A latch key
3. A pen
4. A train ticket
5. A map of the District of Bogong, Victoria

For Test 1 68 listeners visualised a penny, with 3 placing it correctly as the first object. In Test 2 624 listeners mentioned a key but only 6 designated it a latch or Yale key. Test 3 resulted in 2,384 listeners identifying a pen with 140 placing it correctly as the third object. No mention of a train ticket in Test 4, although listeners identified a tram ticket. Test 5 resulted in 112 listeners stating various types of map of which 48 were placed as the fifth object and 1 was a map of Victoria. In no case was a map of the District of Bogong identified. Again this test did not produce a conclusive result. *The New York Times* focussed specifically on the role of radio in the experiment when it said “The question as to whether telepathy has any real analogy with radiotelepathy is one that must remain, for some time at least, unanswered.”<sup>72</sup>

The initial high level of listener interest in the radio 3LO Melbourne experiment resulted in it being repeated in August 1928. This time a series of articles consisting of an ash tray, a ball of twine, a pair of scissors, a paper clip, a flashlight and a pair of headphones were visualised by the three ‘senders’. This follow up experiment appears to have been less successful than its predecessor in 1927, with only ‘hundreds of replies’ and many listeners having ‘missed the point’ of the test altogether by reporting scenes and past events rather than articles. Supporters of the experiment remained upbeat, stating that “So much has been accomplished during the past few years in the transmission of waves of sound and sight in the fields of radio activity and television that it is within the bounds of possibility that waves of a similar character, of which at present we know nothing, may

also possibly be transmitted through space.”<sup>73</sup> That being said the 3LO experiment appears not to have been repeated again.

In Germany Dr. Alexander Herzberg conducted a far more scientifically rigorous radio telepathy experiment in Berlin in October 1927 soon after the initial BBC test. The Berlin test resulted in 2092 audience responses from subjects around Germany, resulting in 12,552 individual responses in total.<sup>74</sup> The experiment had a twofold purpose: first to prove the method applied in the earlier BBC test and second to apply a new approach in an attempt to find proof of telepathy. The Berlin test of radio telepathy was the first to rely exclusively on a suite of cards made up of:

1. 10 maps in postcard format numbered 0 to 9
2. 10 identical maps in different colours
3. 10 picture postcards with 10 portraits of various important figures.

Results of the tests were tabulated and subject to lengthily statistical analysis. This study concluded that both London and Berlin tests resulted in nothing that supported telepathy and that the BBC test methodology was flawed.<sup>75</sup> On the other hand the Berlin researchers found ‘nothing against telepathy’ either. The use of card based telepathy tests and the rigid application of method were to become features of ongoing telepathy research throughout the 1930s.<sup>76</sup>

Despite the relative failure of this series of telepathy experiments commercial radio interests in the United States recognised a public appetite for such events. In July 1929 the NBC launched the

network programme ‘*The Ghost Hour*’, using the psychic and mentalist Joseph Dunninger to conduct a 30 minute demonstration of telepathy.<sup>77</sup> (Fig. 15) This demonstration consisted of Dunninger concentrating on three objects, namely a President of the United States, three digits and a simple diagram. The programme was broadcast on WJZ New York, WJR Detroit, WGY Schenectady, WREN Kansas, KWK St. Louis and KDKA Pittsburgh. Whilst ‘*The Ghost Hour*’ was short lived, Dunninger re-emerged on radio in the 1940s to become ‘The Master Mind of Mental Radio’ through a series of successful radio programmes.<sup>78</sup>



Fig. 15 . Joseph Dunninger

The notion of mental radio also found its way into popular literature by the late 1920s. In 1928 and 1929 the Pulitzer Prize-winning author Upton Sinclair conducted a series of 300 telepathic tests on his wife Mary Craig Kimbrough. Upton Sinclair devised his own method to test telepathic ability,



whereby he would make a drawing and place it in an envelope. In another room Mary would "tune in", retrieve the image and draw her own copy. The result was *Mental Radio*, which was published in 1930 and carried a preface by no less than Albert Einstein.<sup>79</sup> Like those before him Upton Sinclair likened thought transference to electromagnetic radiation when he asked:

"Can a thought or image in one mind be sent directly to another mind and there produced and recognized? If this can be done, how is it done? Is it some kind of vibration, going out from the brain, like radio broadcasting?"<sup>80</sup>

Both the Dunninger radio act and Upton Sinclair's book signalled the passing of the idea of mental radio into popular culture by the late 1920s. Yet just as the expression *mental radio* was merging into the general public's consciousness, the electromagnetic analogy used to explain telepathy for the previous fifty years was about to pass. Part of the reason for this was the decline in the theory of the ether which only a few scientists such as Sir Oliver Lodge continued to cling to.<sup>81</sup> The universe of twentieth century physics, governed by quantum theory and relativity, was vastly different from the clockwork one envisaged by Newton, Maxwell and Lodge.<sup>82</sup> New theories based on new scientific analogies and metaphors would arise in further attempts to explain telepathy to the next generation of believers.<sup>83</sup>

## THE ZENITH RADIO EXPERIMENTS OF THE 1930s

The broadcast experiments of the 1920s were not the end of the association between radio and telepathy. The card test formats pio-

neered by scientists such as Drs Gardner Murphy and Herzberg were improved and combined with rigorous experimental methods by Dr J. B. Rhine at Duke University in the 1930s to produce the Zener Cards tests. In 1937, armed with Dr Rhine's research methods it was Eugene McDonald, the driving force behind the first radio broadcast telepathy experiment in 1924 and head of the Zenith Corporation, who launched the most comprehensive series of radio telepathy tests the world would ever see.<sup>84</sup>

Joseph Banks Rhine (Fig. 16) and his wife Louisa originally graduated with Ph.D.s in Botany from the University of Chicago (Louisa in 1923, J.B. in 1925). Influenced by the writings and lectures of such figures as Lodge and Conan Doyle they decided to commit themselves to psychical research in 1926.<sup>85</sup> In fact Rhine attributed his conversion to psychical research to a lecture he attended delivered by Sir Arthur Conan Doyle, which was probably given in Chicago during Conan Doyle's first tour of the United States in June 1922.<sup>86</sup> The Rhines began to work closely with William McDougall, who had recently supervised Gardner Murphy at Harvard. By September 1927 McDougall and the Rhines had moved to the new Duke University.

Together with Dr Karl E. Zener, Rhine developed a deck of 25 cards in 1931 containing five symbols (a rectangle, a circle, a cross, a star and wavy lines) to be used in telepathy experiments which later became known as Zener Cards. Once established at Duke University, J.B. Rhine concentrated on bringing scientific discipline to the study of telepathy and clairvoyance. Rhine referred to

both as *Extra - Sensory Perception* (ESP) as early as 1932 and by 1934 had published an influential academic monograph carrying that title<sup>87</sup> and went on in April 1937 to establish the



Fig. 16. J.B. Rhine

*Journal of Parapsychology* as a vehicle for serious studies in the field.

Rhine was a good publicist and cultivated a number of key relationships with science writers working in the popular press in the 1930s, particularly those associated with *Scientific American*. J. Malcolm Bird, who had covered the station WOR radio telepathy experiment for *Scientific American* in 1924, was one of these writers. In the mid 1930s articles on the field of parapsychology were also regularly appearing in *Time*, *Forum*, *American Weekly*, *Liberty* and *Reader's Digest*<sup>88</sup>, many of which were penned by Rhine himself. With the publication of *Mental Radio* in 1930 Rhine commenced a regular correspondence with Upton Sinclair and often cited this book in his own writing. Rhine's attempt at popular writing came in October 1937 when he published an account of the Duke University experiments of the 1930s in *New Frontiers of the Mind* which was promoted as Book-of-the-Month when it was initially released and became a bestseller with a general readership. It was Rhine's ability to cross from academic to popular content in the field of ESP that created an ideal platform for the re-emergence of broadcast telepathy tests.

After the publication of *Extra-*

*Sensory Perception* in 1934 Rhine had been initially approached by the NBC radio network to develop a series of broadcast telepathy experiments. In fact the growing public interest in ESP led *New Current Digest* in January 1937 to predict that "Within a few months mental radio - telepathy and clairvoyance - will be America's leading indoor sport".<sup>89</sup> Eugene McDonald, founder and President of the Zenith Radio Corporation, had a long standing interest in psychical research, which some have said stemmed from his mother's psychic abilities.<sup>90</sup>(Fig. 17)

By his own account McDonald conceived of the idea of conducting a new series of radio telepathy experiments in March 1937 and by May had contacted Rhine to commence planning for the project along with Drs Gardner Murphy and Gault. McDonald had a grand vision for the broadcasts and initially expected 69 radio stations throughout the United



Fig. 17. Eugene F. McDonald

States to participate in the tests. The attorney Irving Allen negotiated with radio networks for programming on behalf of The Zenith Foundation, finally settling a contract with the NBC Blue Network for a 52 week run.

In July 1937 McDonald wrote enthusiastically to Rhine declaring "We have a big job on our hands... to entertain the American Public by making them think".<sup>91</sup> However by August Rhine appeared to be having second thoughts when he wrote to McDonald indicating that "my appearance on the program in any conspicuous way will be bad for me and my work".<sup>92</sup> This point marked the start of Rhine's progressive withdrawal from the project with primary academic support now coming from Drs Goodfellow and Gault from Northwestern University who joined the project in return for assistance given by Zenith to research conducted on behalf of the American Institute for the Deaf-Blind.<sup>93</sup> McDonald and Rhine remained on good terms throughout the split with Zenith taking responsibility for the patenting, manufacture and distribution of the Zener ESP cards prior to the commencement of the broadcast tests. (Fig. 18)

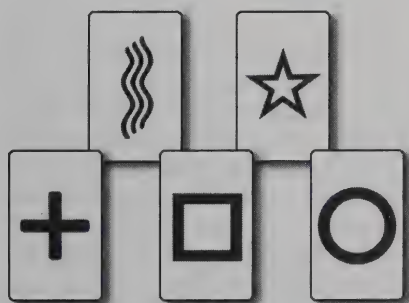


Fig. 18. Zener Cards

The final format of the programmes reflected a compromise between commercial sponsorship, entertainment, and the academic rigour Rhine had originally hoped for and largely accounts for Rhine's withdrawal from the broadcasts. The work Rhine and McDonald undertaken in May and June 1937 demonstrates that they both initially agreed that the telepathy tests needed to be approached through a series of 'audience builders', in which historical scientific breakthroughs were portrayed as a struggle with the orthodox views of the time. This would be used to frame any subsequent discussion of the new science of parapsychology in the radio programmes. Such a format was ultimately adopted for the first three broadcast programmes. However the breakdown in the relationship between McDonald and Rhine appears to be over the actual testing methodology itself: McDonald the showmen needed to produce an entertaining programme whilst Rhine the scientist was only interested in the purity of scientific method.

The first programme went to air on Sunday 5<sup>th</sup> September 1937 at 10.00 p.m. EST and was heavily promoted by Zenith in the press and trade journals. The actual telepathy experiments were to commence on 26<sup>th</sup> September 1937 and continued until 2<sup>nd</sup> January 1938. These programmes largely concentrated on descriptions of psychic incidents with a few minutes of each devoted to a telepathy test. The test themselves involved ten 'senders' who were students at Northwestern University concentrating on symbols randomly selected by a specially devised machine. Tests were repeated several times in each



programme. The audience were asked to record their responses to each test and mail them in for recording and analysis. A variety of test symbols were used including those used on Zener ESP cards. The tests were as follows:

**Table I : Zenith Radio Telepathy Tests 26 September 1937 to 2 January 1938<sup>94</sup>**

Date	Test Sequences	Number of Subjects Responding (audience members)
26 Sept. 1937	Five (5) Black – White spaces on a roulette wheel	46,433
3 October	Five (5) Vegetables	15,360
10 October	Five (5) Black – White spaces	12,388
17 October	Seven (7) Black – White spaces	17,239
24 October	Five (5) Circle – Cross calls (Zener symbols)	15,447
31 October	Seven (7) Wave – Star calls (Zener symbols)	14,663
7 November	Five (5) Square – Circle calls (Zener symbols)	13,886
14 November	Five (5) Star – Cross calls (Zener symbols)	14,697
21 November	Six (6) Circle – Cross calls (Zener symbols)	19,178
28 November	Five (5) Cross – Star calls (Zener symbols)	20,367
5 December	Five (5) Dark – Light calls	17,548
12 December	Five (5) Heads – Tails coin calls	6,644
19 December	Three (3) Hot – Cold calls	4,499
26 December	Three (3) Ship – Sounds calls	1,651
2 Jan. 1938	Five (5) Light – Dark calls	4,521

Audience participation for the first week was impressive, with 46,433 subjects responding by mail. Audience returns dropped to 15,360 subjects in Week 2 (3 October) through to Week 11 (5 December), with subsequent weeks falling to 6,644 subjects and lower. Falling participation rates may explain a switch of programming to the CBS network in December 1937 until the programme was finally discontinued on 27

March 1938. In all 1,181,715 individual responses to questions were recorded throughout the series of tests making it the largest series of radio telepathy tests in history. Rhine's own attitude to the tests wavered, with the initial results momentarily reigniting his enthusiasm, but by November 1937 he had broken off all official ties.

A number of variations of testing format were introduced during the course of the programmes.

McDonald conducted a separate set of tests for the top 400 respondents to the first broadcast tests using shortwave radio between September 1937 and January 1938. This set of tests involved participants receiving sealed envelopes from Zenith containing a particular card to which the recipient had to write the geometric form they “received” during the broadcast. McDonald continued his private shortwave experiments from his yacht *Mizpah* in December 1937 with a series of six telepathy tests responding to specific questions including events drawn from McDonald’s 1925 expedition to the North Pole. A separate set of tests was also conducted with the second highest scoring individual from the radio tests using 1100 calls on Zener ESP cards. On 13 February 1938 25 groups of people throughout the United States acted as receivers for the radio audience. Even the old chestnut of telepathic communication depending on electromagnetic waves arose in the test of 12 December, when the audience was asked whether they lived in a timber framed or a steel building. The responses to this question did not result in a significant difference between timber and steel constructed buildings.

Overall the first test of 26 September produced a statistically significant result which meant that the total number of correct responses considerably exceeded what would be expected by chance and produced the highest score (known as a critical ratio) of the whole series of 14.8. Zenith placed great weight on this first test which had the highest participation rate, with 118,246 individual correct responses exceeding what could be expected by chance (114,703). In all 10 of the 15 sets

of tests produced positive outcomes in the critical ratio range of 1.0 to 14.8. Five sets of tests produced results less than expected by chance in the critical ratio range of  $-13.7$  to  $-3.5$ . The Zenith Foundation felt the tests vindicated the existence of telepathy, arguing that based on these results the odds were 10,000,000,000,000,000,000 to one against chance.<sup>95</sup>

However the Zenith radio tests produced a vitriolic response from the academic community, fuelled by Zenith publishing a 20 page booklet entitled *What Well-Known Scientists Say about Telepathy* in mid 1938 which claimed the radio tests had both supported proof of telepathy and implied academic support for the position. Dr Goodfellow initially responded relatively mildly by concluding that the Zenith tests were flawed as a consequence of the:

- 1) pattern or sequence used by individuals in recording their guesses had influenced the outcome and
- 2) influence of subtle suggestions in both the broadcast and found in the test instructions that had subconsciously influenced audience responses.<sup>96</sup>

Worse was to come: a committee of the Chicago Psychology Club led by Dr Goodfellow in October 1938 somewhat angrily reported that:

“the Zenith Foundation used without justification the prestige of science and psychology...that they misrepresented the position of psychologists on the topic of extra-sensory perception...that they were dishonest with the radio audience...that they promulgated a superstition by an appeal based on the ‘fallacy of the great name’...that they embarrassed the

few psychologists who attempted to cooperate by announcing... untrue discoveries".<sup>97</sup>

The Zenith Foundation radio telepathy experiments occurred during an intense period of public interest in the field of ESP in 1937 which commenced with the emergence of the *Journal of Parapsychology* and ended with the popular success of Rhine's *New Frontiers of the Mind*. However the loss of Rhine's scientific expertise left the Zenith tests open to academic criticism and led to the alienation of the psychology community. McDonald on the other hand would have claimed the experiments were both a success and also added substantial credibility to the field of ESP research in the mind of the general public.

In the seventy years since the Zenith tests were performed the link between broadcasting and telepathy has persisted. The work of Cazzamali was extended by the Soviet researcher Leonid Leonidevitch Vasiliev from the 1920s through to the 1960s<sup>98</sup>, whilst the advent of the television era led to a new round of mass telepathy experiments<sup>99</sup>. However despite this work a recent analysis of these tests concluded that the results represented outcomes that did not significantly differ from chance<sup>100</sup>.

### CONCLUSION: MENTAL RADIO AND THE BROADCAST TELEPATHY EXPERIMENTS

The broadcast telepathy experiments of the 1920s and the emergence of the idea of mental radio was the culmination of a journey that had commenced in the 1840s with the advent of the telegraph. Along the way great scientific

minds had developed an electromagnetic explanation for telepathy and with it writers, artists, entertainers and musicians had popularised these ideas in the early twentieth century at the beginning of the wireless era. Broadcasting provided the opportunity to test these ideas and to engage a curious public in entertaining attempts at mass telepathy. In turn the tests gave those studying telepathy the opportunity to develop their methods of measuring the success or otherwise of their experiments using a mass audience response. These early broadcast tests served to promote discussion of telepathy by the general public and added some legitimacy to what was at best considered a marginal scientific enterprise. At the close of the 1920s mental radio had established itself as a shorthand expression to describe how telepathy might work, even if the analogy was about to be superseded by more recent scientific developments. By the 1930s the Zenith radio experiments were taking place at the height of a new public interest in the emerging science of Extra-Sensory Perception and supported the repositioning of psychic research into the increasingly mainstream scientific pursuit of ESP. Whilst the radio was not the electromagnetic carrier of the telepathic wave as some had originally imagined, by the late 1930s it had carried the idea of telepathy to an audience of millions.

### ENDNOTES

- 1 See e.g. Susan J. Douglas **Listening In Radio and the American Imagination** Time Books 1999 (Chapters 1 and 2); Jeffrey Sconce **Haunted Media : Electronic Presence from Telegraphy to Television**



- Duke University Press 2000; Pamela Thurschwell **Literature, Technology and Magical Thinking, 1880-1920** Cambridge University Press 2001; Roger Luckhurst **The Invention of Telepathy** Oxford University Press 2002; William Boddy, **New Media and Popular Imagination : Launching Radio, Television, and Digital Media in the United States**, Oxford University Press 2004 at pp.7-24; Anthony Enns 'Psychic Radio : Sound Technologies, Ether Bodies and Spiritual Vibrations', **Senses and Society**, Volume 3 (2) July 2008 pp.137 – 152.
- 2 Janet Oppenheim **The Other World: Spiritualism and Psychical Research in England 1850 -1914**, Cambridge University Press 1985.
  - 3 On the Hydesville incident see e.g. Barbara Weisberg **Talking to the Dead : Kate and Maggie Fox and the Rise of Spiritualism** HarperCollins 2004 ; Sconce **op. cit.** at pp.22-26.
  - 4 Alan Gauld **The Founders of Psychical Research** New York 1968
  - 5 'Faraday on Table-Turning' **The Medical Times and Gazette** July 2 to December 31 1853 at pp.42-43 ; Lewis Campbell and William Garnett **The Life of James Clerk Maxwell** London 1884 at pp.189, 191 and 228-230.
  - 6 On the origins of psychical research see Thurschwell **op. cit.** at pp.15-20, Luckhurst **op. cit.** at pp.66-92.
  - 7 The Society for Psychical Research had six research committees, one of which focussed on thought-transference: See Luckhurst **op. cit.** at pp.51-114.
  - 8 Oppenheim **op. cit.** at p.396.
  - 9 See e.g. Richard J. Stokes 'Telegraphy is an Occult Art: Cromwell Fleetwood Varley and the Diffusion of Electricity to the other World' **British Journal for the History of Science** 1999 Volume 32 pp.421-459.
  - 10 The notion of the ether was fundamental to nineteenth century scientific thinking. See e.g. David B. Wilson 'The Thought of Late Victorian Physicists: Oliver Lodge's Ethereal Body' **Victorian Studies** Volume 15 (1) 1971 at pp.29-48.
  - 11 Frederic Myers brother Arthur is said to have coined the term 'syntony' in relation to wireless telegraphy: see Luckhurst **op. cit.** at p.79.
  - 12 Cited Luckhurst **op. cit.** at p.113.
  - 13 **Proceedings of the Society for Psychical Research**, Volume 7 1891-2 at p.328.
  - 14 Luckhurst **op. cit.** at p.109.
  - 15 'First Report on Thought-Reading', **Proceedings of the Society for Psychical Research** 1882-1883 at pp.33-34 cited in Thurschwell **op. cit.** at pp.28-29.
  - 16 See W.P. Jolly **Sir Oliver Lodge** Constable London 1974 at p.101 ; David Edwards 'A Victorian Polymath' in Peter Rowlands and J. Patrick Wilson (eds) **Oliver Lodge and the Invention of Radio** PD Publications Liverpool 1994 at pp.36-37.
  - 17 Oliver Lodge, 'An Account of Some Experiments in Thought-Transference' **Proceedings of the Society for Psychical Research** Volume 2 1884 at pp.191ff ; Luckhurst **op. cit.** at p.79.
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Graeme Bartram



# Origins of the Edison Medal on its 100<sup>th</sup> Anniversary

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## ABSTRACT

The Edison Medal is the principal medal of the Institute of Electrical and Electronics Engineers (IEEE). It is the most prestigious award given in the United States and Canada in the fields of electronics and electrical engineering. Many of the most important people responsible for developing radio, television and electronic communications received the medal for their groundbreaking contributions. Initiated by Samuel Insull and supported by J.P. Morgan and Andrew Carnegie, the medal was inaugurated with great fanfare. Nevertheless, the medal endured years of neglect, a redesign and controversy. In the end, the Edison Medal was treasured by its recipients and became a legacy of honor to those who made the modern electronic world. This article reveals the previously untold history of the Edison Medal's early years on the occasion of its 100<sup>th</sup> anniversary.

The Edison Medal is the most prestigious award given in the United States and Canada recognizing meritorious accomplishments in the fields of electronics and electrical engineering. The year 2009 marks the 100<sup>th</sup> anniversary of the medal named in honor of America's most famous inventor, Thomas Alva Edison. Edison's work exemplifies the development of large scale industrial research laboratories, the creation of new technology and the installation of the first complete electrical systems in the 19<sup>th</sup> century. Over its history, many of the most important contributors to the development of electronics have been presented the Edison Medal in recognition of their critical roles in laying the foundations of the modern electrical world. This article presents the story of the Edison Medal, its origins and its legacy of honor.

## EDISON AT THE TURN OF THE CENTURY

By the end of the 19<sup>th</sup> century, Thomas Alva Edison had achieved fame, wealth and notoriety. He was known as the "Wizard of Menlo Park" for the many inventions that originated from his research laboratory in New Jersey; including the phonograph and electric light. In 1886, Edison relocated to a new, larger facility in West Orange, New Jersey. A small laboratory was also set up in 1886 at his new summer home in Fort Myers, Florida. Increasingly, he focused his attention on refining the phonograph and on his new film and motion picture businesses. Edison's work on the alkaline battery and his Portland cement operations also looked promising. The 1903 release of the film *The Great Train Robbery* put Edison into the headlines again. Edison's list of accomplishments was well established, and he was a household name in America and in Europe. His long standing and well publicized feud with George Westinghouse and

Nikola Tesla over the effectiveness of alternating versus direct current did not seem to diminish his public image. And, by the opening years of the 20<sup>th</sup> century, those battles too were subsiding.<sup>1</sup>



Fig. 1. Thomas Alva Edison.  
(Photo by Bachrach. Miller, 1931)

### ORIGINS OF THE EDISON MEDAL

1904 marked the 25<sup>th</sup> anniversary of the Edison incandescent lamp. Samuel Insull, Charles Batchelor and a group of Edison's friends, former employees and associates decided to commemorate the anniversary on the occasion of Edison's birthday.<sup>2</sup> The first meetings of the Executive Committee formed to organize the event were held in December 1903 as the group rushed to prepare for Edison's February 11, 1904 birthday. (Documents, Minutes: Dec. 23 and 30, 1903)

The Executive Committee quickly prepared a circular to solicit contributions. The circular, dated January 1, 1904, identified

Samuel Insull as the Chairman and Charles Batchelor as Vice-Chairman of the Edison Medal Association. It also named the 30 member Executive Committee and 124 additional members of the Edison Association. Among the notables identified were J. Pierpont Morgan, R.A. Fessenden, W.S. Mallory, Frank Sprague and Nikola Tesla. The group planned to name an endowed academic medal after Edison that would be awarded through the American Institute of Electrical Engineers (AIEE). The AIEE would act as trustee of the medal.

The Edison Medal Association intended to raise \$7,000 to fund the medal and expenses of the association, of which \$5,000 would represent the principal balance of the endowment. Annual interest on the balance would fund future expenses and annual awards. The Executive Committee set an impossibly short time frame of only 30 days to solicit subscriptions. (Documents, 1904a)

The Executive Committee faced logistical difficulties in completing all their preparations before the February celebration. They selected the National Sculpture Society to assist with the medal design; but, at the close of January 1904, the subcommittees responsible for the medal design had not selected an appropriate image of Edison or decided on a sculptor for the medal. (Documents, Minutes, Jan. 20, 1904) Given the impending date of the celebration, the Committee decided it would formally present the legal agreement establishing the Edison Medal and convey the trusteeship of the Edison Medal to the AIEE without presenting the medal itself. (Documents, 1904b) The Committee rushed to draft their Deed of Gift ("Deed") over the next

# Edison Medal Association

Dear Sir:

In view of the fact that the year 1904 marks the twenty-fifth anniversary of the successful introduction and commercial development of the incandescent lamp, it is deemed appropriate to celebrate so significant an occasion. The friends and associates of Thomas Alva Edison, the pioneer with whose work this great event in electrical history is so closely identified, desire, therefore, to pay him some timely tribute in recognition of what he has thus contributed, as well as in other respects by notable inventions and by unremitting effort, to the advance of electrical science, application and industry. No other twenty-five years in history have equaled this period in the benefits bestowed on mankind by the electrical arts, or in the profitable employment given to capital and labor.

New York  
January  
First

Fig. 2. 1904 Subscription for Edison Medal (Documents, 1904a)

three weeks.

The Deed and corresponding rules governing the Edison Medal specified that the Edison Medal Association would annually recognize a student graduating from any U.S. or Canadian university or military academy who presented the best thesis on an original topic about theoretical or applied electricity and magnetism. Competition was restricted to no more than two students from any one institution. Each student had to complete at least two years of residence and coursework at the university and be no older than 25 years of age. The thesis was restricted to 6,000 words (approximately 20 typed pages). The award would be presented annually on Edison's birthday, February 11. The Deed also specified that the Edison Medal Association, under the auspices of the National Sculpture Society, would host a competition to finalize the medal's design after Edison's birthday. (Science: 1904a and 1904c)

## EDISON CELEBRATION

Five hundred people attended the commemorative dinner on

February 11, 1904 celebrating Thomas Edison's 57<sup>th</sup> birthday and the 25<sup>th</sup> anniversary of the Edison incandescent light. The affair was held at the Waldorf Astoria Hotel in New York. Addresses were made by the President of the AIEE, J.B. Arnold, and A.E. Kennelly of Harvard University, C.F. Brackett of Princeton University, Joseph McCall and C.L. Edgar. Samuel Insull presented the Deed of Gift inaugurating the Edison Medal. (Science, 1904b; New York Times, 1904)

Edison sat under a display of flags and 57 electric lamps. According to eyewitness accounts, he was reserved in public and was too modest to speak. Sugar models of his inventions were placed on tables in front of him. Edison's original telegraph key and quadruplex sender sat on the table in front of Edison positioned at his right hand. Wires stretched across the room to a Marconi wireless transmitting apparatus. Thousands of electric bulbs were strung along the galleries. Over one hundred waiters served ices "contained in models of motors, phonographs, switchboards, automo-



biles, incandescent apparatus, dynamos, megaphones and batteries, the ices themselves being in the form of incandescent bulbs." Each guest went home with a small ivory box with a woman bearing a light and inscribed "Genius with the Lamp" or a miniature incandescent lamp pin. The menus included a picture of a bronze bust of Edison with the words "The Wizard" with Edison's autograph below the image. (Jones, 1908; New York Times, 1904)

Congratulatory messages were received from notables around the world. Andrew Carnegie called Edison the "King of Telegraphers". President Theodore Roosevelt congratulated Edison "as one of those Americans to whom America owes much..." Lord Kelvin cited his "gratitude to Edison [for his] useful and well worked-out inventions for the public". Finally, Edison's own message of thanks was read aloud. It stated, in part, "...Your expressions of goodwill gratify me greatly...This medal is founded to encourage young men to devote their best thought and work to electrical development. I rejoice in this stimulus to harder study...God bless them and you, my dear friends, and this American Institute of Electrical Engineers." (Jones, 1908)

The highlight of the evening occurred when Edison telegraphed "73 - Congratulations and best wishes" on his original quadruplex telegraph instrument. The message was carried across the wires and broadcast by the Marconi wireless equipment. (New York Times, 1904; Jones, 1908) Samuel Insull, Chairman of the Edison Medal Association, then formally presented the Deed of Gift to Professor Arthur Kennelly who received it on behalf of the AIEE.

## THE MEDAL'S FIRST YEARS

The medal was intended to "serve as an honorable incentive to the youth of America to maintain by their works the high standard of accomplishment by the illustrious man whose name and features shall live while human intelligence continues to inhabit the world." (Science, 1904c) The annual student award was to include a parchment certificate and a gold medal funded by the annual interest earnings on the gift. Unfortunately, after the 1904 celebration, little progress was made.

The gift fund was deposited with Continental Trust Company of New York. But three years passed and no medals were awarded. In February 1907, the Edison Medal Committee appointed a subcommittee "to propose a statement of the difficulties that the Committee had experienced in obtaining competitors for the medal under the present Deed of Gift and to recommend to the Medal Committee such modifications...as might seem proper in their judgment under the circumstances." (Gherardi, 1907)

## THE JOHN FRITZ MEDAL

Meanwhile, as the Edison Medal languished, the John Fritz Medal, the highest American award in the engineering profession, was being presented each year. Established in 1902, it recognized scientific or industrial achievement in any field of pure or applied science. Fritz had achieved fame and recognition for his development of American iron and steel manufacturing. The John Fritz Medal was established on Fritz's 80<sup>th</sup> birthday by the American Institute of Mining En-

gineers (AIME), the American Society of Civil Engineers (ASCE), the American Society of Mechanical Engineers (ASME), and the American Institute of Electrical Engineers (AIEE).<sup>3</sup>



Fig. 3. John Fritz Medal.  
(John Fritz Legacy, 2005)

The Fritz Medal eventually included the American Association of Engineering Studies (AAES) as well, and rotated among all five engineering societies that made up the successor organizations. The first four Fritz Medals were given to John Fritz (1902), Lord Kelvin (1905), George Westinghouse (1906) and Alexander Graham Bell (1907).

Thomas Edison received the fifth Fritz Medal in 1908 for his “invention of the duplex and quadruplex telegraph; the phonograph; the development of a commercially practical incandescent lamp; the development of a complete system of electric lighting, including dynamos, regulating devices, underground system protective devices and meters.” (John Fritz Medal, 1910)

## EDISON MEDAL RESTRUCTURED

In 1908, the Executive Committee of the Edison Medal Association now decided to revamp its medal’s rules and intended purpose. Arthur Kennelly later ex-

plained that between 1904 and 1908 a shortage of applicants led to the absence of qualified candidates under the existing rules which focused the award on student recipients. (Presentation to

Tesla, 1917) The Committee responded by redefining the medal’s purpose and executed an Amended and Substitute Deed of Gift Creating The Edison Medal (“Amended Deed”) in New York on March 26, 1908.<sup>4</sup>

The new deed re-established the Edison Medal in partnership with the New York Trust Company and the American Institute of Electrical Engineers (AIEE). It reasserted that the medal “should, during the centuries to come, serve as an honorable incentive to scientists, engineers and artisans, to maintain by their works the high standard of accomplishment set by the illustrious man whose name and features shall live while human intelligence continues to inhabit the world.” The Amended Deed also re-wrote the rules and established that the AIEE would present the medal as its award for “...MERITORIOUS ACHIEVEMENT [*emphasis in document*] in Electrical Science or Electrical Engineering or the Electrical Arts, whenever in the judgment of said Committee [there is someone] properly deserving of such award...” (Documents, 1908a) Revisions to the Committee’s by-laws commenced in October 1908, and the final draft was presented to the Board of Directors on December 11, 1908. (Edison Medal Committee, 1909) The Board approved the minutes on May 18, 1909, making operative

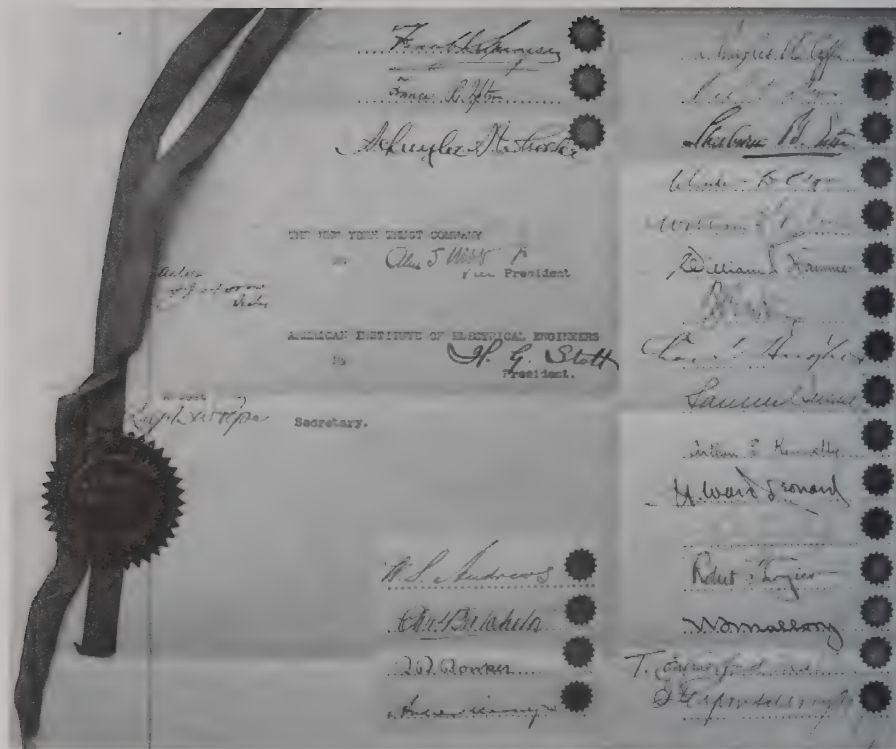


Fig. 4. Signature Blocks from Amended and Substituted Deed of Gift Dated 1908 Reestablishing Terms for the Edison Medal.<sup>5</sup>

the revised by-laws and new rules. (Edison Medal Committee, 1910) Later, the AIEE appointed a jury of 24 members to select the recipient of the award. (Presentation to Nikola Tesla, 1917)

## A DESIGN FOR THE MEDAL

The 1904 Edison Medal Committee had initiated a Programme and Rules governing its competition to select an appropriate design for the medal. (Documents, 1904c) Working under the auspices of the National Sculpture Society, designs were invited within a general scheme that specified Thomas Edison's portrait would dominate the face of the medal and an allegorical design would appear on the reverse side. Edison's image would date from

the time of his incandescent light, approximately 25 years earlier. A prize of \$1,000 would be awarded to the selected artist for production of the medal. Designs were due from April 25-30, 1904, with a decision to be rendered within one month. The jury for the competition included Daniel C. French<sup>6</sup>, Augustus Saint Gaudens<sup>7</sup> and J.Q.A. Ward<sup>8</sup> of the National Sculpture Society and Edward Adams and T. Commerford Martin on behalf of the Edison Medal Association. (Documents, 1904c)

The design contest was administered late in 1904, and on Nov. 11, 1904, James Earle Fraser<sup>9</sup>, a New York sculptor and medallion designer, was informed by St. Gaudens that he was the unani-



## Programme and Rules

For a Competition for the Selection of a Design for an Edison Medal  
Commemorating the Invention of the Incandescent Lamp

Under the Auspices of the National Sculpture Society

NEW YORK, February 20, 1904.

Fig. 5. 1904 Programme and Rules for the Edison Medal Design.  
(Documents, 1904c)

mous selection of the jury. St. Gaudens asked Fraser to provide several sketches "showing modifications to your present idea, or of new ones that may occur". (Freundlich, 2001)

The final design featured both Edison and an allegorical symbol of merit. The obverse (face) features Edison's portrait and is inscribed "Awarded By The American Institute of Electrical Engineers for Meritorious Achievement In Electricity". The reverse (back) depicts "The Genius of Electricity Crowned by Fame" showing an angel standing behind a male nude and a glowing Edison light sitting on a pedestal.<sup>10</sup> (New York Times, 1909; Freundlich, 2001) The Amended Deed specified that the AIEE would retain a die for future production and reproduction of the gold medal. (Documents, 1908a)

### FIRST RECIPIENT IN 1909

Prior to issuing the Amended Deed which redefined the Edison Medal, five graduate students who had qualified to compete for the medal under the old 1904 rules had submitted their theses. Since the medal had been restructured to focus on lifetime achievement

instead of student work, the five candidates were asked to withdraw from the medal competition in 1908. They were allowed to resubmit their theses in a special contest to receive a Diploma of Merit plus a \$150 cash award issued by the AIEE. (Edison Medal Committee, 1909) On May 18, 1909, Trygve Jensen, a graduate student at the University of Illinois, won the Diploma of Merit for his research on the "Operation of a 100,000 Volt Transformer." (Edison Medal Committee, 1910)

Finally, five years after the initial 1904 organization of the Edison Medal Association, the Committee was ready to officially name its first Edison Medal recipient.<sup>11</sup> Dr. Elihu Thomson was cited for his "meritorious achievement in electrical science, engineering and arts as exemplified in his contributions thereto during the past 30 years." (Edison Medal Committee, 1910; Brittain, 2004) Thomson's accomplishments included approximately 700 patents, work on electric arc lighting, establishing the Thomson-Houston Electric Company (which would eventually merge with the Edison General Electric Company to become General Electric Com-



Fig. 6. The First Edison Medal Awarded to Elihu Thomson In 1909. (IEEE Global History Network, Images 410 and 535)

pany), the Thomson Electric Meter, alternating current devices, the electric air drill, and methods of electric arc welding. In the 1890s, Thomson investigated X-rays and performed research on fused quartz for use in reflecting astronomical telescopes. Thomson was active in the AIEE, contributed to many other societies and received the John Fritz Medal in 1916. He later became the President of the Massachusetts Institute of Technology.<sup>12</sup> The Edison Medal Association presented Thomson with a parchment certificate constituting official notice of the award at the AIEE's annual dinner on February 24, 1910. He received the gold Edison Medal at the AIEE's annual meeting on May 17. (Edison Medal Committee, 1910)

## CONFLICTS AND CONTROVERSY

The Edison Medal has been awarded annually since 1909 with the exception of 1915, 1926, 1964 and 2003. The 1926 medal was actually rejected by the named recipient, Dr. William Coolidge, who refused to accept

the medal in light of a U.S. Circuit Court decision invalidating his patent on ductile-tungsten. The decision stated that a patent (for an invention) could not be awarded for a scientific discovery. The Edison Medal Committee still tried to award the medal, but Dr. Coolidge refused to "detract from the luster of that medal which should stand as one of the most coveted prizes for meritorious work in the electrical field." (New York Times, 1927)

Ironically, most of the Edison Medal awards in its first ten years went to pioneers or supporters of alternating current and arc lighting technologies even though Edison's long standing opposition to alternating current systems was well known and had garnered many newspaper headlines. (Jonnes, 2003; McNichol, 2006) The rules did not require Edison to present the award, and he was not involved with the award committee's selection of recipients. The following innovators of alternating current technology received Edison Medals during its first decade: Elihu Thomson (1909), Frank Sprague (1910),

George Westinghouse (1911), William Stanley (1912), Charles Brush (1913), Nikola Tesla (1916) and Michael Pupin (1920). (See Note 11)

George Westinghouse received the 1911 Edison Medal for his groundbreaking work developing alternating current systems for power distribution and lighting. After nearly 25 years of battling Westinghouse over the alternating current versus direct current systems, Edison offered Westinghouse no congratulations at the ceremony. (McNichol, 2006) Westinghouse ignored Edison stating that "If I have had any success in life it has been due to my wife." (Jonnes, 2003)

In 1917, the Edison Medal was presented to another former Edison rival, Nikola Tesla, for his development of polyphase and high frequency electric currents. (Edison Medal, 2009; IEEE Internet Site, 2009c) Rumors had circulated in 1915 that both Tesla and Edison might jointly share the Nobel Prize in Physics. Though unconfirmed by the Nobel Committee, Tesla allegedly rejected the award and would have nothing to do with Edison. Contradictory stories followed. Soon thereafter, the 1915 Nobel Prize was presented to two British scientists.<sup>13</sup>

The following year, the Edison Medal Association selected Tesla as its 1916 medal recipient. Although Tesla was listed on the original 1904 Edison Medal General Committee subscription (Documents, 1904a), he was now unwilling to receive an award named after Edison. Tesla further thought that his contributions to wireless telegraphy and radio had been slighted since Guglielmo Marconi had already received the Nobel Prize in 1909 with Carl F. Braun. Tesla initially refused the

nomination in anger, but later agreed to accept the Edison Medal after his friends at the AIEE pled with him to overcome years of hostility, bitterness and competitive rivalry with Edison. (Cheney, 1981 and 2001) Tesla stunned the audience at the presentation ceremony when he graciously accepted the award and complimented Edison, who did not attend the ceremony, as "this wonderful man, who had had no theoretical training at all, no advantages, who did all himself, getting great results by virtue of his industry and application." (Presentation to Tesla, 1917)

Tesla treasured the Edison Medal during his final years. Poverty stricken, he gave up virtually all of his personal possessions, but kept the medal in a safe at his subsidized Hotel New Yorker apartment. Tesla is reported to have proudly shown the medal to many visitors. After his death on January 7, 1943, Tesla's nephew opened the safe to discover that the medal was missing. It has never been recovered. (Cheney, 1981 and 2001; Tesla Memorial Society, 2009a)

The Edison Medal for 1947 was presented to Lee De Forest by none other than David Sarnoff, President of the powerful Radio Corporation of America (RCA) and a one-time litigant both with and against De Forest over patent rights. Sarnoff heaped glowing praise on De Forest's grid-controlled electron vacuum tube as "one of the twenty great inventions of all time". (New York Times, 1947)

## CONNECTIONS

The Edison Medal winners are well represented among the recipients of the John Fritz Medal, and many were also members in



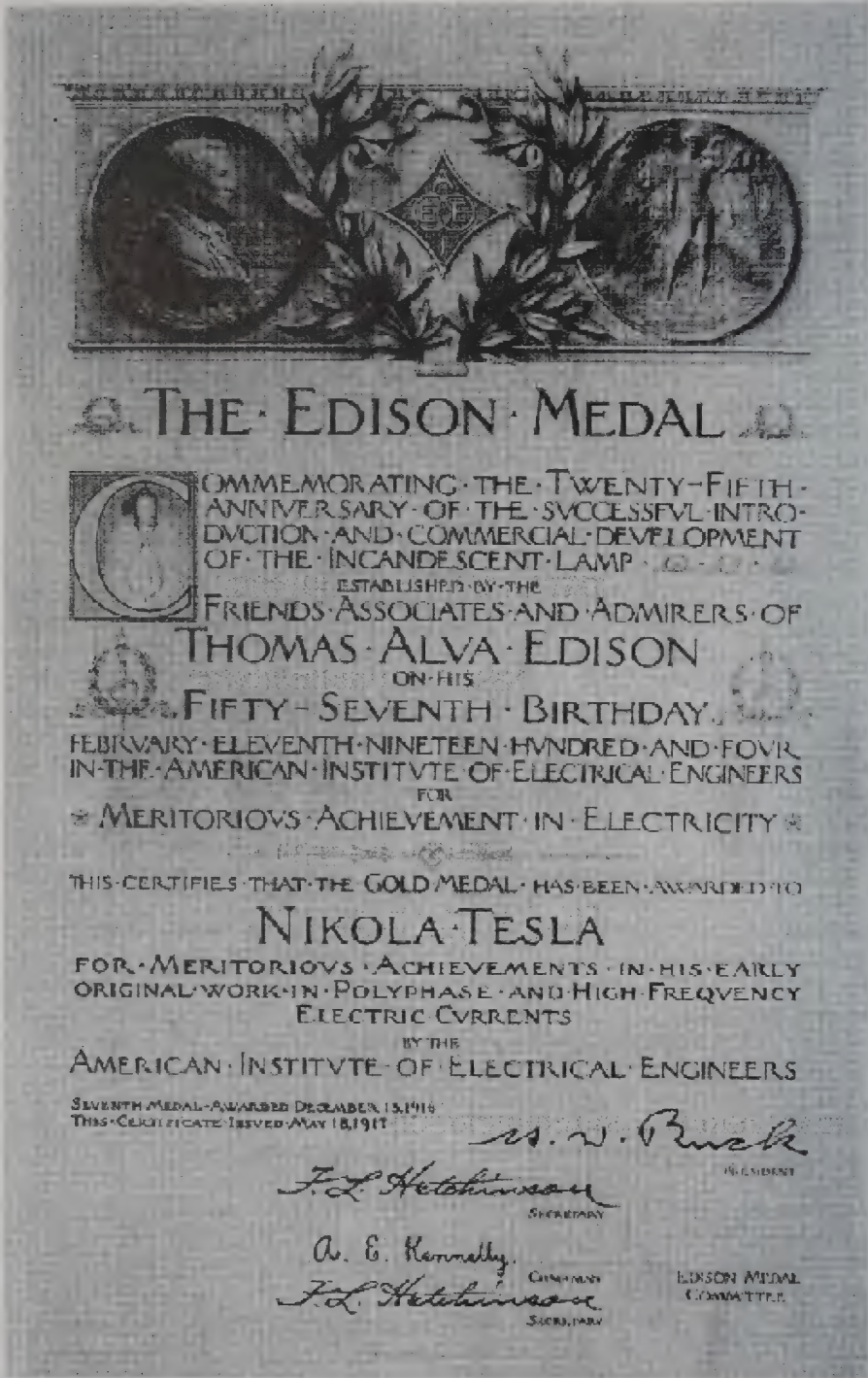


Fig. 7. Nikola Tesla 1916 Edison Medal Award Certificate. (Kesler, 2006)

the most prestigious national engineering honor society in the U.S., Tau Beta Pi. Of the 103 John Fritz Medal winners from 1902-2008, 52 are also Tau Beta Pi members. Of the 13 people that won both the John Fritz Medal and the Edison Medal, six were Tau Beta Pi members. These include Michael Pupin (who won the Edison Medal in 1920), Frank Jewett (1928), Vannevar Bush (1943), Charles Kettering (1958), Walker Cisler (1965) and George Brown (1967). The remaining medalists include Elihu Thomson (1909), Frank Sprague (1910), John George Westinghouse (1911), Alexander Graham Bell (1914), Carty (1917), Willis Whitney (1934) and Philip Sporn (1945).<sup>14</sup>

The Edison Medal was awarded to a number of people for their critical roles in developing radio and television communication, including Michael Pupin (1920) for his work in mathematical physics and its application to the electric transmission of intelligence; Frank Conrad (1930) for radio broadcasting and short wave radio transmission; Arthur Kennelly (1933) for the theory of electrical transmission and international electrical standards; Edwin Armstrong (1942) for the regenerative, super-regenerative and super-heterodyne circuits and frequency modulation FM radio; Lee De Forest (1946) for the grid-controlled vacuum tube; and Vladimir Zworykin (1952) for the television. (Edison Medal, 2009; IEEE Internet Site, 2009c)

## ARMSTRONG AND MILLIKAN

Edwin Armstrong was particularly introspective upon his receipt of the 1942 Edison Medal after his many years spent in litigation

with De Forest, RCA and others over radio patents and public acknowledgement of who invented various radio circuits. The AIEE awarded Armstrong an honorary lifetime membership (the first of which had been extended to Lord Kelvin in 1892) together with the Edison Medal. Armstrong's Edison Medal citation noted the importance of his work stating, "This keystone of radio development was later to become involved in fourteen years of litigation and which, in the end, was decided by lay courts based on errors of fact and judgment which were contrary to the scientific facts." (Lessing, 1956)

Alan Hazeltine presented the award to Armstrong stating "...one development stands out from all others...the application of the three-electrode vacuum tube...the original electronic tube was the two-electrode vacuum tube of Edison, in whose honor the Edison Medal was established. Others subsequently applied the "Edison Effect" in radio detection [but] the real foundation for the unlimited development was laid by the Edison Medal recipient, Dr. Edwin Howard Armstrong." (Hazeltine, 1943)

Armstrong's acceptance speech began, "It is not possible for me to find the words to tell you what this honor means to me. To have belonged to the generation which learned the meaning of volts and amperes when Edison was at the height of his career, to be able to follow in the footsteps of my old instructor - Michael Pupin - who stood here twenty-two years ago, and to have my own work appraised, during these difficult days, as worthy of the Edison Medal, gives it an inspiring meaning that can never be described." (Armstrong, 1943)

In 1922, Robert Millikan won the Edison Medal “for his experimental work in electrical science”. He was the first recipient to be honored primarily for scientific contributions rather than engineering or invention. The selection committee is rumored to have been influenced by his leading role in the mobilization of science and engineering to carry out military research during World War 1. The award proved timely, since the following year he received the Nobel Prize in Physics, becoming the first and only Edison Medalist to win this prestigious recognition. (Brittain, 2006; IEEE Global History, 2009)

### EDISON’S 1928 CONGRESSIONAL MEDAL

Thomas Edison is revered as one of the great American inventors. He is recognized in the applied fields of industrial research, engineering and electronics for his many inventions and in science for his discovery of the “Edison Effect”. Edison was long recognized as holding the largest number of U.S. patents awarded to any American, eventually obtaining 1,093 patents.<sup>15</sup> The U.S. Congress presented Edison with a gold medal in 1928, three years before his death, “for development and application of inventions that have revolutionized civilization in the last century.” (Act, 2007) Among those present to witness President Coolidge’s presentation of the Congressional Medal were Dr. Elihu Thomson, the Edison Medal’s first recipient, and the first Chairman of the Edison Medal Association, Samuel Insull. (New York Times, 1928)

### THE LEGACY OF THE EDISON MEDAL

In 1963 the Institute of Radio Engineers (IRE) and the AIEE merged to form the Institute of Electrical and Electronics Engineers (IEEE). The IRE’s former Medal of Honor, its highest award first given to Edwin Armstrong in 1917, was selected to be the IEEE’s “highest award”. The Edison Medal was selected to become the IEEE’s “principal medal”.<sup>16</sup> Its purpose remains the same today as in 1909. As Arthur Kennelly stated over seventy years ago, the Edison Medal was intended to identify those “great and noteworthy” and those “great and notorious and worthy of merit”, serving as a “Who’s Who” in the field of electronics and electrical engineering. (Presentation to Tesla, 1917)

Today, the Edison Medal is the oldest award in the areas of electrical and electronics engineering. Samsung Electronics Co., Ltd. agreed to sponsor the IEEE Edison Medal in 2006 and is committed to the sponsorship through 2016. (IEEE Foundation, 2005) The Edison Medal is considered the highest American award “for a career of meritorious achievement in electrical science, electrical engineering or the electrical arts.” (IEEE Internet Site: 2009b and 2009c)

Nominations and the selection of award recipients are governed by the IEEE Medals Council of the IEEE Awards Board. The award is based on “leadership, individual contributions, originality, breadth, patents/publications, other achievements, honors, duration of dominance, quality of nomination”. (IEEE Internet Site: 2009c and 2009d)

The original award included a gold medal, bronze replica, small



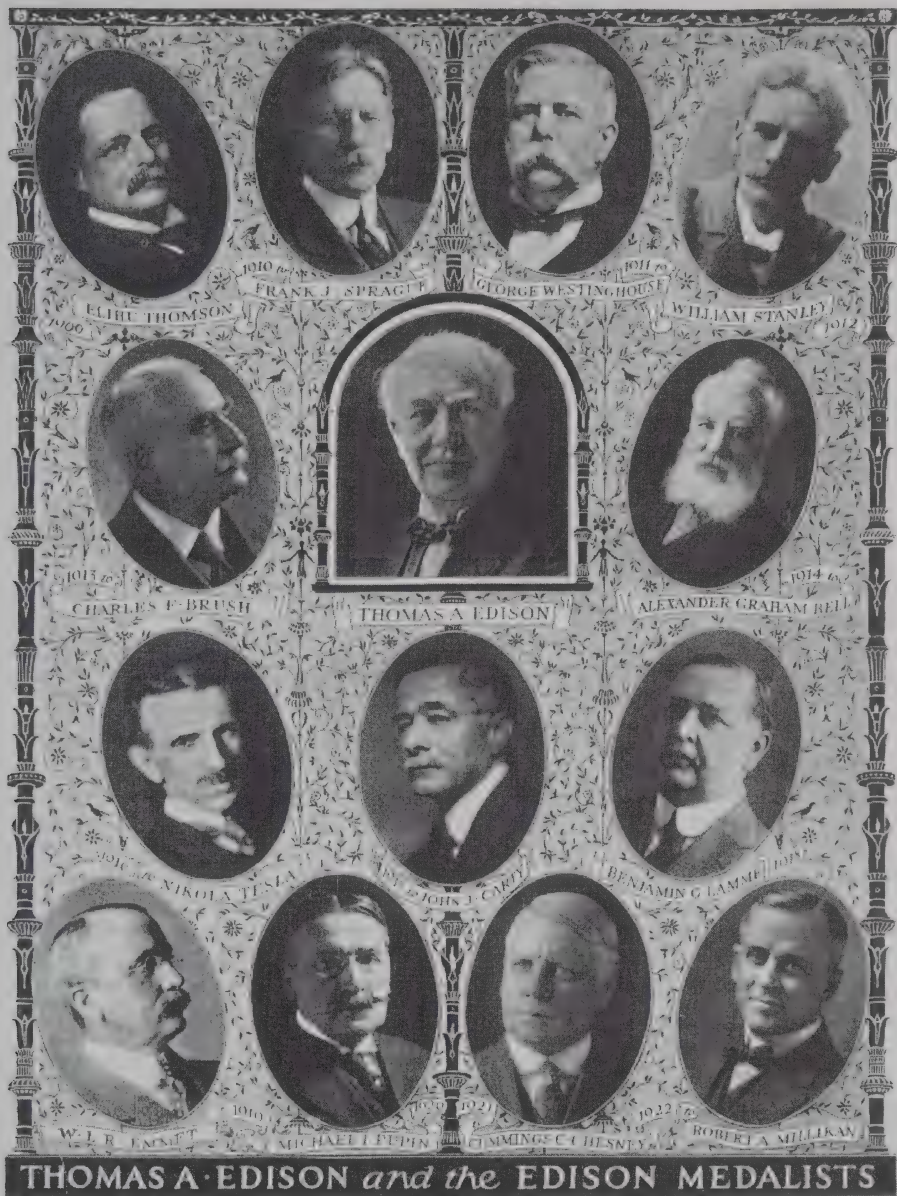


Fig. 8. Edison Medal Winners 1909 through 1922.  
(Tesla Memorial Society, 2009b)

gold replica, certificate and honorarium. (IEEE Edison Medal, 2009) Today's prize includes a \$10,000 honorarium, gold medal, gold pendant and certificate. (IEEE Foundation, 2005)

The 2009 Edison Medal was

awarded to Tingye Li, a retired division manager of the Communications Infrastructure Research Laboratory at the AT&T Laboratories in Holmdel, New Jersey. (IEEE Medal Recipients, 2009c) His work in the field of broadband

**Table 1. 100 YEARS OF THE EDISON MEDAL**

1909	Elihu Thomson	1961	William B. Kouwenhoven
1910	Frank J. Sprague	1962	Alexander C. Monteith
1911	George Westinghouse	1963	John R. Pierce
1912	William Stanley	1964	(no award)
1913	Charles F. Brush	1965	Walter Lee Cisler
1914	Alexander Graham Bell	1966	Wilmer L. Barrow
1915	(no award)	1967	George H. Brown
1916	Nikola Tesla	1968	Charles F. Avila
1917	John J. Carty	1969	Hendrik W. Bode
1918	Benjamin G. Lamme	1970	Howard H. Aiken
1919	William L. Emmet	1971	John W. Simpson
1920	Michael I. Pupin	1972	William H. Pickering
1921	Cummings C. Chesney	1973	B. D. H. Tellegen
1922	Robert A. Millikan	1974	Jan A. Rajchman
1923	John W. Lieb	1975	Sidney Darlington
1924	John W. Howell	1976	Murray Joslin
1925	Harris J. Ryan	1977	Henri Busignies
1927	William D. Coolidge	1978	Daniel E. Noble
1928	Frank B. Jewett	1979	Albert Rose
1929	Charles F. Scott	1980	Robert Adler
1930	Frank Conrad	1981	C. Chapin Cutler
1931	E. W. Rice, Jr.	1982	Nathan Cohn
1932	Bancroft Gherardi	1983	Herman Paul Schwan
1933	Arthur E. Kennelly	1984	Eugene I. Gordon
1934	Willis R. Whitney	1985	John D. Kraus
1935	Lewis B. Stillwell	1986	James L. Flanagan
1936	Alex Dow	1987	Robert A. Henle
1937	Gano Dunn	1988	James Ross MacDonald
1938	Dugald C. Jackson	1989	Nick Holonyak
1939	Philip Torchio	1990	Archie W. Straiton
1940	George Ashley Campbell	1991	John Louis Moll
1941	John B. Whitehead	1992	G. David Forney, Jr.
1942	Edwin H. Armstrong	1993	James H. Pomerene
1943	Vannevar Bush	1994	Leslie A. Geddes
1944	E. F. W. Alexanderson	1995	Robert W. Lucky
1945	Philip Sporn	1996	Floyd Dunn
1946	Lee De Forest	1997	Esther M. Conwell
1947	Joseph Slepian	1998	Rolf Landauer
1948	Morris E. Leeds	1999	Kees A. Schouhamer Immink
1949	Karl B. McEachron	2000	Jun-Ichi Nishizawa
1950	Otto B. Blackwell	2001	Robert H. Dennard
1951	Charles F. Wagner	2002	Edward E. Hammer
1952	Vladimir K. Zworykin	2003	(no award)
1953	John F. Peters	2004	Federico Capasso
1954	Oliver E. Buckley	2005	Peter Lawrenson
1955	Leonid A. Umansky	2006	Fawwaz T. Ulaby
1956	Comfort A. Adams	2007	Russel D. Dupuis
1957	John K. Hodnette	2008	Dov Frohman-Bentchkowsky
1958	Charles F. Kettering	2009	Tingye Li
1959	James F. Fairman	Source: IEEE Internet Site, 2009c. (See Note 11)	
1960	Harold S. Osborne		

optical fiber communications seems far removed from Thomas Edison's incandescent light first commemorated by Edison's friends and associates 105 years ago.

The tremendous progress achieved in electronics and electrical science over the past century, which is characterized by the recipients of the Edison Medal, has made it a living testament to the life and work of its namesake, Thomas Edison.

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## NOTES

- 1 The "War of Currents", or "Battle of Currents", raged from the mid-1880s through the first years of the twentieth century. George Westinghouse and Thomas Edison became bitter adversaries due to Edison's ruthless

## Edison Medal

promotion of direct current (D.C.) for electric power distribution over the alternating current (A.C.) systems advocated by Westinghouse and Nikola Tesla. The battle was waged in newspapers, the courts and through various banking and business dealings. Contracts for major lighting and power installations such as the Columbian Exposition and propaganda over the first electric chair provided the public with numerous newspaper headlines. (Jonnes, 2003; McNichol, 2006)

2 A number of these former employees and associates of Edison would later form the Edison Pioneers in 1918. This group was established to memorialize Edison through public works including preserving Edison artifacts and historic places, funding scholarship medals and building memorials. The group met annually on Edison's birthday. The original Edison Pioneers included 28 members and 230 former associates of Edison. The following are noted in particular:

- (1) Edison's 'four principal assistants': Charles Batchelor (Chairman of the Edison Medal Assn.), Edward Johnson, John Kruesi and Francis Upton (Edison Medal Assn.);
- (2) Edison's 'co-workers': Charles Edgar (Edison Medal Assn.) William Hammer (Edison Medal Assn.), Samuel Insull (Executive Committee of Edison Medal Assn.), Frances Jehl (Edison's assistant at Menlo Park and his biographer), Robert Lozier (Edison Medal Assn.), T. Commerford Martin (Edison Medal Assn. and editor of *Electrical World*), John Ott (Edison Medal Assn.);
- (3) Edison's 'associates': Richard Bowker (Edison Medal Association), Henry Ford (founder of The Edison Institute later known as the Henry Ford Museum and Greenfield Village); Arthur Kennelly (awarded Edison

Medal in 1933), Frank Sprague (awarded Edison Medal in 1910), Nikola Tesla (awarded Edison Medal in 1916) and Theodore Vandeventer. (New York Times, 1918; Hammer, 1920; Miller, 1931; Kennelly, 1932; Edison Pioneers, 2009)

- 3 For a complete history of John Fritz and the Fritz Medal including its winners, see *Science*, 1902; John Fritz Medal: 2009a and 2009b; John Fritz Medal, 1910; Trainer, 2008.
- 4 The Amended Deed was executed in triplicate by the full Executive Committee including William S. Andrews, Charles Batchelor, Richard R. Bowker, Andrew Carnegie, Charles A. Coffin, Richard N. Dyer, Sherburne B. Eaton, Charles L. Edgar, William E. Gillmore, William J. Hammer, Frank S. Hastings, Charles T. Hughes, Samuel Insull, Arthur E. Kennelly, H. Ward Leonard, John W. Lieb Jr., Robert T. Lozier, W.S. Mallory, T. Commerford Martin, J. Pierpont Morgan, John Ott, Frank J. Sprague, Francis R. Upton, and Schuyler S. Wheeler. Alex S. Webb signed as Vice President of the New York Trust Company and Henry G. Stott signed as President of the AIEE. Eugene H. Lewis, who had executed the original 1904 deed, had since died. John Ott's signature was omitted from Samuel Insull's copy of the Amended Deed, which was delivered to the Edison Medal Association's lawyers as the final copy. (Documents: 1908a and 1908b)
- 5 Signatures are in alphabetical order on the Deed of Gift (see Note 4), but are shown in the following order in the excerpts: (Left column top) Sprague, Upton, Wheeler; (Left column middle) Webb, Stott; (Left column bottom) Andrews, Batchelor, Bowker, Carnegie; (Right column) Coffin, Dyer, Eaton, Edgar, Gillmore, Hammer, Hastings, Hughes, Insull, Kennelly, Leonard, Lieb, Lozier, Mallory, Martin, Morgan.



- 6 Daniel French designed several renowned public monuments including *Abraham Lincoln* at the Lincoln Memorial in Washington, D.C., the *Minuteman Statue* in Concord, Massachusetts and *Republic*, the centerpiece of the World's Columbian Exposition in Chicago, 1893. (French, 2009)
- 7 Augustus Saint Gaudens was a sculptor and artist who designed many public monuments including *William Tecumseh Sherman* in New York City's Central Park, *Diana and Hiawatha* at the Metropolitan Museum of Art in New York City, the *Robert Gould Shaw Memorial* on Boston Common and *The Puritan* in Salem, Massachusetts. He also designed the Double Eagle \$20 U.S. gold coin as well as the \$10 Indian Head gold eagle. (Gaudens, 2009)
- 8 Artist and sculptor John Quincy Adams Ward is best known for his statue of *George Washington* on the steps of Federal Hall on Wall Street in New York City. (Adams, 2009)
- 9 James Earle Fraser was the leading American sculptor of public monuments of his generation. Today, no other artist has more public sculptures on display in the U.S. He is best known for the U.S. Buffalo Nickel as well as *Theodore Roosevelt* at the American Museum of Natural History in New York City, *Benjamin Franklin* at the Franklin Institute in Philadelphia, the entry sculptures and pediment reliefs at the U.S. National Archives building in Washington, D.C., *Alexander Hamilton* at the U.S. Treasury in Washington, D.C., and the *End of the Trail* sculpture now at the National Cowboy & Western Heritage Museum. Fraser also executed the Thomas Edison bust and seated Edison statue at the Henry Ford Museum in Dearborn, Michigan. (Semple, 1910; Freundlich, 2001)
- 10 The original design for the reverse (back) of the Edison Medal depicted a nude male sitting on steps holding a glowing Edison light bulb. Fraser actually cast Edison's own arm holding the light bulb for this version of the medal. (Freundlich, 2001)
- 11 The Edison Medal award dates in this article are based on the dates each recipient was selected, as reported by the IEEE, and not the dates the awards were presented, as reported by some of the reference materials. Since recipients were selected at the close of each calendar year and the medal presentation was made the following year, there is some inconsistency referring to the year of each award.
- 12 Dr. Elihu Thomson is not related to Sir William Thomson, known as Lord Kelvin. In addition to the Edison Medal, Thomson was the first American recipient of the Kelvin Gold Medal issued by the Institute of Civil Engineers in Great Britain in 1923. The Kelvin Medal is awarded for "distinguished service in the application of science to engineering." (Presentation to Thomson, 1917; Brittain, 2004; IEEE Explore, 2008; ICE, 2009)
- 13 See New York Times (1915) for the original article and Cheney (1981 and 2001) for the complete story which involved many unsupported newspaper articles and interviews about the Nobel Prize award. On November 14, 1915, the Nobel Prize Committee announced the 1915 prize for physics would be awarded to Professor William Henry Bragg of the University of Leeds in England and his son W.L. Bragg of Cambridge University for their use of X-rays to determine the structure of crystals.
- 14 See IEEE, 2009c; John Fritz Medal, 2009a and 2009b; IEEE Century of Honors, 1984; IEEE Edison Medal, 2009.
- 15 A 2005 study concluded that the largest number of U.S. patents (1,432) belong to Shunpei Yamazaki working at the Semiconductor Energy Laboratory in Tokyo, Japan. The second highest

number of patents (1,322) belongs to Donald Weber, primarily involving flower pot and flower bundling technology. Thomas Edison now ranks third with 1,093 U.S. patents. (Maney, 2005)

- 16 The American Institute of Electrical Engineers (AIEE) was founded in 1884. The focus of the AIEE would largely become dominated by topics of electric power generation and wire communications. The Institute of Radio Engineers (IRE) was formed in 1912, modeled on the AIEE, but was devoted to radio, wireless telegraphy and electronics. In the 1940s the interests of the two societies began to significantly overlap and many engineers were members of both societies. A merger occurred in 1963, and the resulting organization was renamed the Institute of Electrical and Electronics Engineers (IEEE). (IEEE Century of Honors, 1984; IEEE Internet Site, 2009c) See also Edison Medal, 2009 and IEEE Edison Medal, 2009.

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## ABOUT THE AUTHORS

**David and Julia Bart** reside in the Chicago area. Together, they have published numerous articles on radio and broadcasting history and telegraph communications.

David received both his Bachelor of Arts Degree in Anthropology and Statistics (1985) and his Masters Degree in Business Administration (1993) at the University of Chicago. He is a member of the Board of Directors of the Antique Wireless Association, Technical Curator for the Museum of Broadcast Communications in Chicago, and President of the Antique Radio Club of Illinois. He has made presentations on communications history at the New York Historical Society, the American Association of Physics Teachers and American Association For The Advancement of Science Joint AAPT/AAAS Meetings, and the Antique Wireless Association. He is also a member of the Michigan Antique Radio Club and the Indiana Historic Radio Society.

Julia received her Bachelor of Arts Degree in Behavioral Sciences (1987) from the University of Chicago and a Master of Arts in Reading from Concordia University (2007). Julia is a long time member and past Treasurer of the Antique Radio Club of Illinois where she continues to play an active role as a volunteer. Julia is also a member of the Michigan Antique Radio Club and the Indiana Historic Radio Society.

David and Julia recently became founding members of the new Webster Club which will explore the history of scientific instruments at the Adler Planetarium in Chicago. David and Julia have collected radio, tele-

phone, phonograph and telegraph devices for over 20 years; and, with their two sons John and Michael, have enjoyed providing numerous demonstrations and programs for the Boy Scouts of America, school groups and local historical societies.



Julia and David Bart





*AWA Review*

## Professor David Edward Hughes

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**ABSTRACT**

Our society and technology is built on the pioneering work of the Victorian scientists. Unfortunately, with the passage of time, only the popular names are remembered. If we peel away this top layer though, we can discover a host of scientists that not only made important discoveries but also led fascinating lives. One of these scientists was Professor David Edward Hughes FRS. His printing type telegraph instrument invented and used in America was also instrumental in the growth and success of the communications network of Europe. His work on suppression of electrical interference and discovery of the carbon microphone led to improved telephone communications and experiments with his induction balance led to the metal detector. His wireless experiments, for which he had invented a unique detector enabling him to receive a transmission over distance of 500 yards with his mobile receiver in 1879-1880, are a tribute to his ingenuity.

In the earlier part of the 1800's, electricity was a novelty - a scientific orphan. Then suddenly, (in historic terms), all that changed. A number of clever experimenters observed that electricity could actually travel vast distances instantaneously along wires, and sought to put this phenomenon to good use. When these pioneers cracked open Pandora's box, they had no idea that it would lead to such a diverse and all encompassing communications industry that we all rely on today. The technologies that we now take for granted, can be traced back to the pioneering work of the industrious Victorian scientists.

One of these was Professor David Edward Hughes. Hughes was a brilliant inventor and practical experimenter as well as a gifted musician, ever inquisitive and a true lover of science. He was born when Michael Faraday and Joseph Henry were still uncovering the mysteries of "electricity", a time when they and others were wrestling with the observations that electricity could create magnetism, and magnetism could be used to create electricity. He lived through a period rich in famous names that are still familiar today, such as William Thomson (Lord Kelvin), Cyrus Field, Samuel Morse, Thomas Edison and Alexander Graham Bell.

Hughes was to leave his mark through his inventions and discoveries in the fields of telegraphy, telephony, wireless, metal detection, and audiology. He was an international scientist whose life was spent between America, Britain, and Continental Europe, and became one of the most decorated scientists, receiving high honors from no less than nine countries. Hughes was one of the few self-made scientists who were able to amass a substantial sum of money over their lifetime, which upon his death he generously donated to the London Hospitals. However, like many of the early scientific foot soldiers that laid down the founda-

tions of our communications industry his name has tended to sink below the history horizon. (Fig. 1)



Fig. 1. Prof. David Edward Hughes

David Hughes according to his tomb inscription was born in 1830. His father, originally from Wales, and a boot maker by trade, was a gifted musician who moved to London, married and had four children. David Hughes and his two brothers and sister appeared to have inherited their father's gift and also turned out to be natural musicians.<sup>1</sup> This talent wasn't wasted, as an infant musical troupe was formed and toured the music halls of London and the provinces. They were billed as the "Child Prodigies" and went on to perform for the Royal Family and other notables. (Fig. 2). Buoyed by their success, the child prodigies musical show was taken on tour to America, which opened its arms to the child performers. Their popularity and novelty led to the honor of performing at the White House. After several years of show business they had acquired significant wealth and the

family retired from the entertainment business to take up touring for pleasure. Their travels were extensive, covering North America from Nova Scotia to New Orleans. Any thoughts of returning to the old country appear to have slipped away.

During this period of adventure, Hughes' father became interested in geology and mineralogy. Probably like so many of the early pioneers, he dreamt of striking it rich and succumbed to "gold fever". Virginia was then the gold hot spot and this is where the family settled down, buying a farm there in the 1840 s. Here they set about farming and mining for the elusive ore.<sup>2</sup>

During their travels, the children's education was not neglected and a private tutor traveled with them. David Hughes showed the same flare for the sciences as he had for music. He was both inquisitive and inventive and his father built a laboratory next to the farm. Here, Hughes spent his time carrying out chemistry experiments, taking mechanisms apart, building new ones, and making improvements to their mining equipment. Hughes was living in an interesting time that would see the birth of many new technologies throughout his lifetime. One of these was the transition of electricity from a poorly understood phenomenon into a technological powerhouse. This occurred when it was applied to the electric telegraph introduced during the 1840's by William Fothergill Cooke and Charles Wheatstone in England and Samuel F.B. Morse and Alfred Vail in America. Overnight, almost, it seems that communication time shrank from months, weeks or days to a matter of minutes.



## THE TELEGRAPH ERA

It was while Hughes was a teenager that he first saw a Morse telegraph system in operation. Always inquisitive when he saw new mechanisms, he questioned the operator as to how it worked. Whilst simple and practical in its operation, it must have set his innovative mind to ponder how such a system could be improved. Over the following few years, he was to bring his ideas to fruition by inventing his own telegraph instrument.

As Hughes came to the end of his teen years, he became restless and tired of the limited amenities

of rural Virginian farm life. People were starting to look to the west for new opportunities and he decided to join the migration. He applied, and was accepted for a post as a professor of philosophy and music at a college in Kentucky. This was somewhat of an accomplishment at his young age but Hughes was proud of becoming a professor, a title he maintained throughout his life. The move to Kentucky in 1850 turned out to be a tough period for him as he had limited money and had to juggle his time to accommodate teaching, taking on private music students and experimenting with his ideas for a new telegraph instrument.<sup>3</sup>



Fig. 2. The "Child Prodiges"

During this period, Hughes started to formulate how he could implement the telegraph instrument he had in his mind. He decided that instead of using codes that required operator training as well as requiring multiple pulses to be transmitted, it would be better if one could just type in the message directly as alphabetical characters and print them out at the receiving station. Hughes was not alone in attempting to invent a better telegraph instrument and a number of systems had or were appearing, using a variety of operating principles and vying for their place either in the European or the American market. These used a variety of signaling methods such as a multitude of short and long pulses as in the Morse system, or a long stream of pulses as in the step by step systems, or signals of different polarity as in the needle or dial systems.

In America, at the time there were only two serious competitors to the Morse system, the Alexander Bain electrochemical telegraph and the Royal Earl House printing instrument patented in 1846 and in operation by 1847.<sup>4</sup> Whilst these instruments were used by some of the telegraph companies, Morse was by far the dominant system and they constantly fought to keep it that way by challenging any attempts by patentees of other systems. Hughes's idea of typing in letters and either displaying or printing them at the receiver was not new, and had been used by Paul Gustave Froment in France and Royal Earl House in America.<sup>5</sup> However, his ideas and approach would result in an instrument that would both look and operate differently.

Hughes is renowned for buying old clocks, dismantling them

and carrying out experiments with the parts. Somewhere in this experimentation, his ideas started to gel as to how he could implement a printing telegraph. His concept was to provide a keyboard so that the letters could be typed in directly, and at the receiving end print out the letters and words onto a paper tape. (Sounds familiar and taken for granted today). One of the most ingenious parts of his telegraph, though, was in its method of transmitting the information from transmitter to receiver. Up to that time, telegraph systems were based on transmitting voltage pulses and used only three parameters: amplitude, polarity and duration in their method of signaling.

Hughes introduced a time element to his scheme. His notes indicate he conceived of a one wave system, (waves were often used to refer to pulses).<sup>6</sup> He had figured out how to transmit all 26 letters of the alphabet using a single pulse. To accomplish this he constructed a keyboard not unlike a manual typewriter, except the keys were arranged in alphabetical order. Next, he constructed a mechanical scanning device that could scan the keyboard to determine when a key had been pressed. This was implemented by using a rotating cylinder that had a helical pattern of 26 protruding pins (not unlike a musical box cylinder), and driven by a clockwork mechanism. (Fig 3).

When a letter key was pressed down, it pushed forward a contact that was struck by a pin of the helix on the rotating cylinder. By connecting a battery across the cylinder and keys, a voltage pulse would be generated whenever a contact was made. The cylinder was rotated at a constant speed in which time it scanned all 26 let-



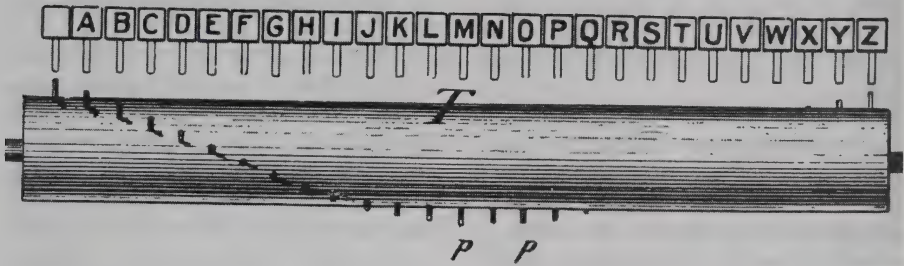


Fig. 3. Helix Scan

ters once each revolution.<sup>7</sup> For example if the "A" key was pressed the first pin on the rotating cylinder would make contact and if "E" was pressed then the fifth pin was struck (but displaced in time by  $5/26$  of a revolution). Thus, he had set up a repetitive time base (equal to the rotation of the cylinder) that was in turn subdivided into 26 time slices. Each time slice could transmit a one or a zero represented by a pulse or no pulse. (In actual practice, Hughes used 28 keys and ran at 120 rpm). Depending at what position the pulse occurred within the time base indicated which letter had been

transmitted. What he had conceived of was a pulse position modulation system that would find many future applications and would later evolve into time division multiplexing. (Fig. 4.)

At the receiver, he arranged for a print wheel (with 26 letters plus the two extra positions - a period and a blank) to rotate at a constant speed and in phase with the scanning cylinder in the transmitter. Below the print wheel was a platen that could be rapidly raised against it. A continuous paper strip was fed over the platen. When a pulse was received, it triggered the platen to be rapidly lifted

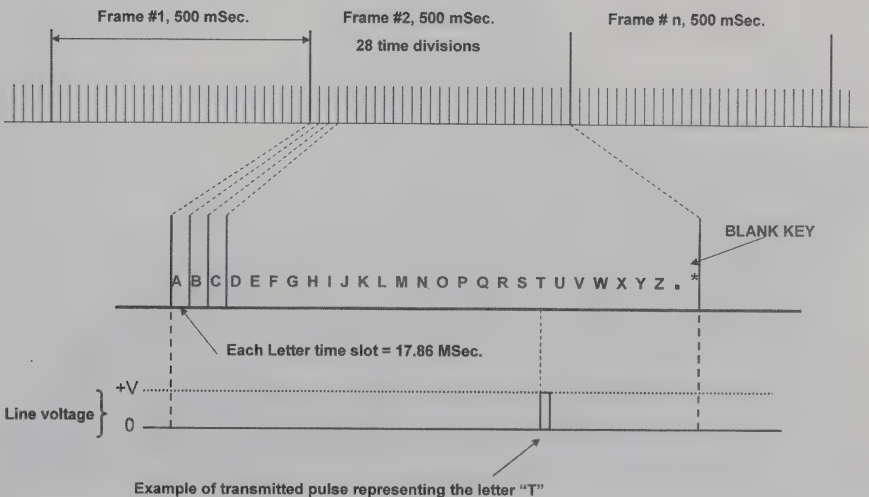


Fig. 4. Pulse Position Modulation



and briefly contact the print wheel and print a letter on the paper tape. Other mechanisms advanced the paper and inked the print wheel. (Fig. 5).

Hughes' challenge was how to get two telegraph instruments to run in perfect synchronism and phase separated by tens or hundreds of miles. Here all his experimenting with clocks came into play. They were at the time the most precise mechanism available. He solved the problem by using a vibrating spring strip to provide the precision timing instead of a pendulum, which would have proved far too slow. The oscillating spring strip drove a typical clock mechanism of an anchor and escapement wheel. The power for the mechanisms was provided by a falling weight drive similar to that used in grandfather clocks. In return, the vibrating spring received a nudge from the escapement wheel each period to keep it oscillating. The vibrating spring was also fitted with a temperature

compensating mechanism to keep the vibrating frequency constant.

Hughes took an approach to the electrical signaling that required minimum power. This was in contrast to other telegraphs such as the Morse instruments. For these, hefty batteries were needed, as all the power to drive the receiver register relay had to be supplied from the transmitting end (although later a local relay was introduced to reconstitute weak signals).

Hughes's approach was based on transmitting lower voltage pulses and using a sensitive detector in the receiver. The detector was a smart piece of design. Hughes used a permanent horseshoe magnet with soft iron pole pieces onto which were wound coils. He then arranged an armature to close across the gap, held by the force of the magnet. The armature had a spring attached that could be tensioned such that it was just about to pull the arma-



Fig. 5. Hughes' original telegraph instrument

ture clear. When a pulse was received, it was routed through the coils. The resulting magnetic field generated was in opposition to that of the permanent magnet thus weakening it. This caused the armature to release and to fly off under the influence of the tensioned spring. Not only did this need a lot less electrical power to operate but also the response of the detector was very rapid. The release of the armature triggered the platen to rise against the print wheel. The actuation power for the receiver was also provided by a falling weight drive. As the printing was able to take place without stopping the print wheel, it contributed to its overall higher operating speed than other systems. Once the platen had operated, it also reset the armature of the detector.

Hughes' design actually integrated a transmitter and receiver into one instrument and it was designed from the start to operate in a duplex mode (able to transmit and receive simultaneously). It was also possible to actually send more than one letter per revolution of the scanning cylinder providing they were spaced a number of letters apart (equal to the time to recycle the receiving relay). For example, the word "fly" could all be transmitted within one revolution, again further contributing to the speed of transmission. The usual quoted average was three letters per revolution, and five was the maximum.

To synchronize instruments there was a procedure to be accomplished. Instruments could initially be accurately set to run at close to the same frequency after manufacture. Then, installed instruments say in New York and Philadelphia were first set to start

in phase. The transmitting instrument and receiving instrument were first latched in the "blank" position. In both instruments, the mechanisms were all running except the print wheel which was declutched from its rotating shaft and held at the blank position and in a wait mode. The transmitting operator then pressed down the blank key on the keyboard. When the receiver detected the blank signal, it unlatched the print wheel setting both instruments to run in synchrony. This clever arrangement also took care of instrument time lags and transmission line lags by automatically offsetting the print wheel equal to the time difference. As these time lags would remain constant, the instruments would remain in synchrony. Time lags up to one revolution of the print wheel could be accommodated (0.5 sec for a rotation of 120 rpm).

Next, to ensure that both instruments were running at the same frequency, the following procedure was used. The transmitting instrument sent out a string of the letter "A". If the receiver printed out a series of A's then they were running at the same frequency. However if the receiver printed out letters that were running away say B, C, D, etc., then the receiver was running too fast or if it was printing Z, X, Y, etc., then it was running too slow. Thus, the frequency of the receiver was adjusted until a series of A's was printed.

The electromagnet arrangement Hughes used in his detector became known as the "Hughes quick acting electromagnet". This component was adopted for use by many other inventors and applications. One of these applications was with railway signaling and safety systems used by Henry

Latique in France and by Sykes' in Britain.

Hughes finally managed to complete his prototype instruments and get them to successfully operate over telegraph lines in 1855 with an average speed of 44 words per minute. Hughes' next move was to patent his instruments and see if he could get the telegraph companies interested in buying the rights. At the time, there were many competing telegraph companies with fragmented operation covering the Eastern part of America. One of their big customers was the newspapers, and in particular, the Associated Press (AP), who had an ongoing battle to reduce the cost of sending their dispatches over the Morse dominated telegraph lines.

It was also a time when Cyrus W. Field had entered the telegraph arena with his grand plan to span the Atlantic with an undersea telegraph cable.<sup>8</sup> However, he and his associates realized that to make their plan work they needed to pull the fragmented telegraph companies into a cohesive operation to be able to provide for smooth message flow to and from their Atlantic cable if it was to be an economic success.

When Hughes had barely completed his prototypes, the AP got wind of his invention and summoned him to New York. If they could acquire Hughes's telegraph, they could put pressure on the Morse telegraph companies by threatening competition to force reduced rates and possibly bring about some cohesion in the industry. AP's common objective with Cyrus Field and the availability of Hughes' new instrument provided the impetus for the New York businessmen to move forward with some bold plans and form the

"American Telegraph Company" (ATC) with Peter Cooper as president and Cyrus Field, David Hughes and others as corporate executives.<sup>9</sup>

The AP played a prominent role in bringing this about. Hughes was offered \$100,000 for his telegraph system - a sum that must have been beyond his wildest dreams. This was to set a pattern for his life, as he always seemed to be just in the right place at the right time with the right product. He was however unaware that his invention was to be a pawn in the American Telegraph Company business dealings. The AP and ATC now had a competing telegraph system and some clout to use against the Morse companies to start forcing them to amalgamate with the ATC and reduce their costs.

Hughes' instrument was assessed as not being robust enough to survive the daily use by telegraph operators. To solve this, the ATC put their experienced machinist, George Phelps to work with Hughes in upgrading the instrument.<sup>10</sup> A relationship that was not always harmonious. The young Hughes protective of his invention and the more senior Phelps - an experienced machinist and familiar with the telegraph instruments of the day was probably full of ideas as to how to improve the mechanisms.

The eventual outcome however was an instrument that was more robust and incorporated various changes and improvements. These were replacing the typewriter type letter keys with a piano style keyboard, changing the mechanical scanning mechanism to a rotating commutator, beefing up the clockwork mechanism, adding a corrector mechanism to keep the instruments in



tight synchronism and combining the transmitter and receiver weight drive mechanism. Manufacturing commenced and the instruments started to be put into service. Hughes patented his original telegraph in England in 1855 and America in 1856.<sup>11</sup> (Fig. 6).

By 1857 Cyrus Field was ready to make another attempt to lay a cable across the Atlantic and invited Hughes to England to join him. Hughes couldn't refuse the challenge and was drawn into the project. The fact that there was insufficient knowledge at the time to know if an electrical signal could be sent through 2000 miles of wire lying under great pressure two miles below the ocean hadn't, so far, deterred Field! The Atlantic telegraph cable is a story unto its self that ended up spanning several years before finally succeeding.<sup>12</sup>

Hughes' involvement briefly

spanned the summer and fall of 1858. He traveled to England where he attempted to make his instrument operate over the cable while it was in storage in tanks at the shipyard. Undersea cables had different characteristics to the traditional telegraph lines strung above ground on poles. The difference being its significantly higher capacitance that had the effect of almost swallowing electrical pulses, which became known as the "embarrassment" of the cable. Hughes was to meet William Thomson (later to become Lord Kelvin) in England, who was a few years older than himself and who had taken the time to devise a formula for the propagation of electrical signals in submarine cables.<sup>13</sup> His telegraph equation or law of squares indicated electrical pulses would experience an increasing time delay as they traversed the cable, known as retardation. A delay in

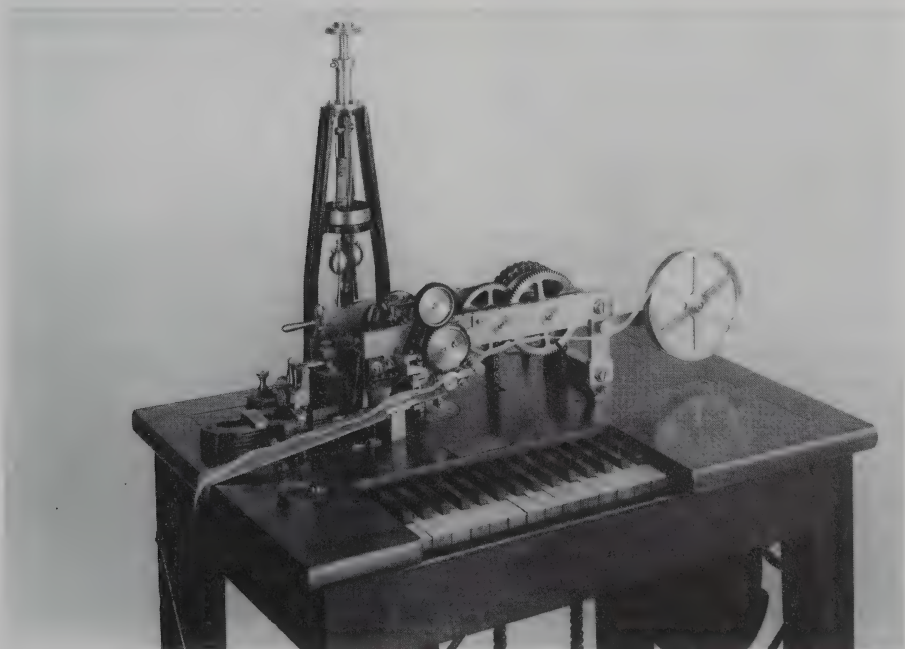


Fig. 6. Later model of Hughes' telegraph instrument

a 100 mile cable would not just increase by a factor of 10 in a 1000 mile cable (if it was linearly proportional) but would increase by a factor of 100. Along with this effect, the signal would also experience attenuation. Thus, sending signals over the cable presented a significant challenge to the instrument technology of the day. The speed that messages could be transmitted was an all-important parameter as the operating economics of the transatlantic cable were dependent upon it.

Unfortunately the electrician for the transatlantic cable, W.W. Whitehouse did not agree with Thomson (an unpaid advisor) and had his own ideas as to how to send signals through the cable. Hughes was caught in between conflicting views and at the same time tried to modify his instrument to run significantly slower to work over the cable. His effort however came to a sudden stop in the fall of 1858 as the cable that had operated for a couple of months went dead.

After the cable failure, Hughes tried to break into the British market dominated by the established "Cooke and Wheatstone" telegraph system, with no success. He contributed to the government's board of enquiry into the transatlantic cable failure. He believed one of the problems was the failure of the insulation. To address this he invented a self-sealing semi- fluid insulation. The idea was that if the gutta percha insulation became punctured the fluid would ooze into the void and re-seal it.<sup>14</sup>

Hughes had decided that there wasn't much point in returning to America since ATC owned the rights to his instrument and the telegraph industry was starting to become monopolized by them,

and eventually, Western Union. His instrument was subsequently further modified by Phelps who combined some of the features from the Hughes and House instrument with his own to construct an instrument that became known as the "Combination Instrument" that remained in service for many years.

Somewhat disillusioned in Britain, Hughes headed for France which was using a fairly old system of their own invention. It turned out they were about ready for an upgrade and open to evaluating new systems. After a successful trial period, his telegraph system was adopted in 1861 - again he just happened to be in the right place at the right time. The French put his system into use on the heavily used telegraph lines and were happy enough with the system and Hughes' performance that they presented him with the Imperial Order of the Legion of Honor by Emperor Napoleon III in 1864. Unlike America, (and initially Britain), where the telegraph companies were private or publicly traded, the continental telegraph companies were all state run.

Adoption of his system then spread to Italy, Russia, Germany, Turkey, Holland, Switzerland, Belgium, Spain and Serbia until it was in operation throughout Europe. It became the standard for all international lines specified by the International Telegraphic Union.<sup>15</sup>

Whilst England initially had given Hughes the "not invented here" treatment when he had tried to introduce his telegraph previously, they eventually had to adopt his instruments to be compatible with the rest of Europe. (Although there was some rumor that they removed his name from

the instrument to avoid embarrassment!). His instruments were put in to use by the United Kingdom Electric Telegraph Company of which Hughes also became a director. By 1869, his instruments were in routine service on many of the cross channel undersea cables.<sup>16</sup>

By the 1870's Hughes' telegraph, system was in widespread use throughout Europe as well as in South America. As a tribute to its design, it continued in service for nearly 100 years finally ending its service in the 1940's. Hughes spent most of the 1860's and early 1870's based in Paris, travelling widely on the continent in support of his telegraph systems where he had licensed a number of manufacturers. During this time he continued to make upgrades and improvements. These included adding numbers and symbols providing up to 56 characters, providing tactile feedback to the operator so as to know when a character had been transmitted, improvements to the timing mechanism and changing over to electric motor drive.

He became known as one of the expert telegraph engineers of the day who was not just in the business of selling instruments but in the business of promoting a communication system. He was also called on to investigate the growing problems of electrical interference and lightning strikes on telegraph installations. He was recognized for his service as he became one of the most decorated scientists of the day receiving honors from all the countries he had systems in. He also received the Gold Medal at the Paris Exhibition in 1867, along with Cyrus Field.

## THE TELEPHONE ERA

In 1877, Hughes decided to move to London, then considered the scientific epicenter. His telegraph system had been so successful that he had become relatively wealthy, allowing him to become financially independent. He was now regarded as one of the pre-eminent telegraph men in Europe and was about to take his place in the scientific circle as an independent researcher.

Alexander Graham Bell had just introduced his telephone, and it was the talk of the town.<sup>17</sup> Whilst it was a wonderful invention, it had its limitations. Hughes, along with others, was quick to recognize this. Bell's telephone used the same electromagnetic component and diaphragm both as a receiver and transmitter. While it worked well for the former, it lacked power as a transmitter and therefore was limited in its signal output, and hence its range of transmission. Hughes decided it would make a good research project.

While he recognized the components as functioning pieces of the telephone he saw them also as splendid pieces of test equipment. The telephone receiver, for him, was a device that enabled the amplitude and frequency range of signals to be easily measured for the first time over a wide dynamic range. He constructed a number of receivers for his own use as pieces of laboratory equipment. Next, he turned his attention to the transmitter. Hughes had actually used and demonstrated an earlier version of a telephone in 1865, when he borrowed a "Telephon" from Prof. Philipp Reis the German scientist. At the time he had been in Russia installing his telegraph system when he was requested to give a lecture to the



Czar and notables on the telegraph and other electrical devices. He included Reis's telephone in the presentation. The Reis telephone had actually been the starting point for many of the early telephone experimenters such as Bell and Edison. Hughes made some experiments trying to improve on Reis's approach but they were unsuccessful.

He next started his enquiry by pondering if there was a material or substance that could convert sound directly into electricity. This line of reasoning was based on the fact that it had been discovered that selenium altered its electrical characteristics when exposed to light. William Thomson had also shown that placing a wire under strain resulted in a change to its resistance.<sup>18</sup> Hughes decided to pursue this approach. He set up a stretched wire to see if he could get it to vibrate when exposed to sound waves, believing that if it did then the strains experienced by the wire would change its resistance which in turn could be detected.

His circuit consisted of a battery, the stretched wire and the telephone receiver, all connected in series. Fortunately, the experiment failed, but it was a failure that set him on a path of discovery. Hughes was a great experimentalist and seemed to be able to sniff out which way to proceed. In the failed experiment, which resulted in the wire being so extended that it broke, he noticed at the point of failure that he could hear in the telephone receiver a rushing sound and then a final crackle. Too many a broken wire or loose connection would be an annoyance but he was intrigued by the sounds he heard when the wire broke, it was something to be investigated. He tried holding the

wires together and found that noises could be heard, he then laid the wires down on the table one on top of the other slightly weighted to hold them together and was surprised that he could hear sound.

He embellished this experiment by laying three nails down to form a letter "H" and connected them into his circuit. Now he could hear even better – but not with much fidelity. He had discovered the loose contact effect as a means of detecting sound. His basic apparatus relied on being able to modulate a current by the loose or poor contact. It was a device whose resistance changed in accordance with the sound waves, just what he had been looking for. He went on to try many different arrangements and materials in a quest to improve the quality of the sounds he could hear. Some of these were glass tubes filled with metal filings, with charcoal pieces or charcoal powder as well as charcoal that had been impregnated with mercury. (Fig. 7).

He tried many types of material contacts and found that metals that oxidized became unusable. Materials that didn't oxidize were platinum and carbon – and he chose the more economical of the two. As he refined his devices he found the most successful were based on a carbon pencil loosely supported between two carbon supports mounted on a piece of wood or sounding board. These he connected in series with a battery and the Bell receiver. He named it a "microphone" – a magnifier of sound (in keeping with the microscope that magnified light). It was a true microphone in that it had many more applications other than just as a telephone transmitter.

He had discovered a true microphone that could be made so sensitive that a fly could be heard walking about on it. He declined to patent the microphone declaring that he was giving the technology away free to be used by anyone. His experiments were published by the technical societies and in many of the technical journals.<sup>19</sup> The floodgates soon opened and within months, others were repeating his experiments and working on their own versions. Variations of the carbon pencil microphone were exten-

sively used in conjunction with an electromagnetic receiver in Europe for many years by several companies. A later variation, based on Hughes's demonstration of the use of particles in loose surface contact, resulted in the carbon granule microphone of Henry Hunnings.

In America this technology was further developed by A. White into what became known as the solid back transmitter and in the UK as the Post Office insert number 13 microphone. The carbon granule transmitter was not su-

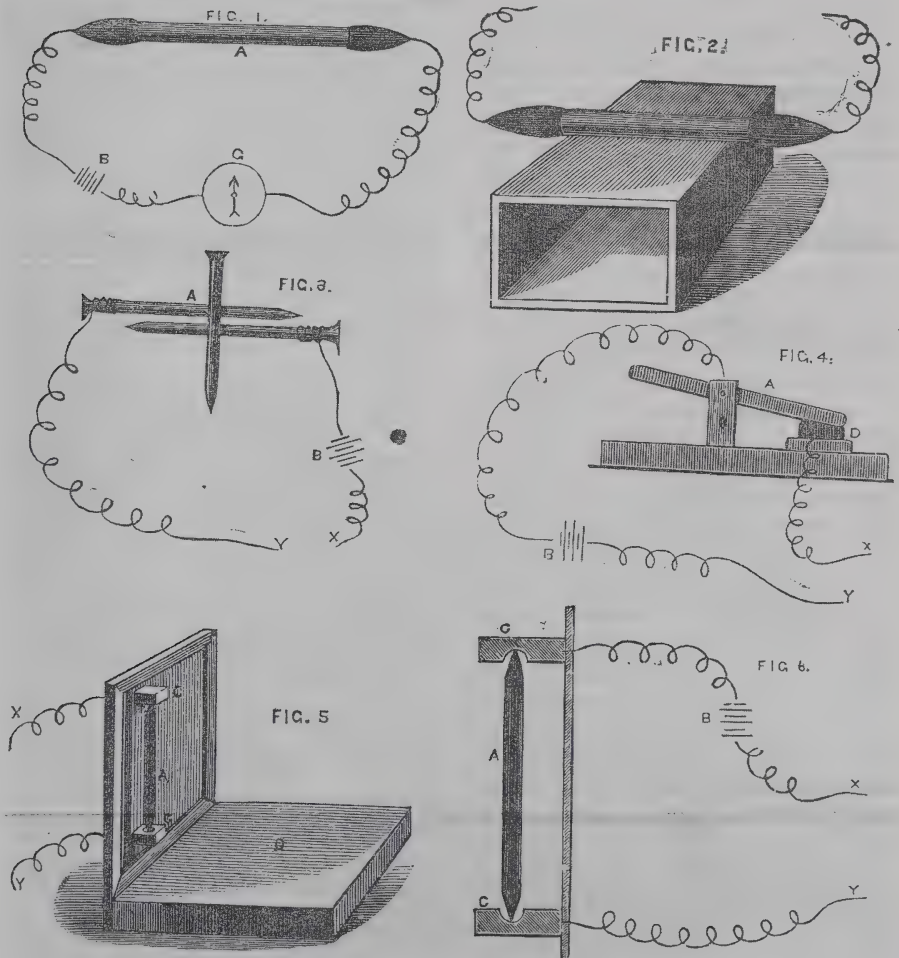


Fig. 7. Various Hughes microphones.

perseded by any other technologies for use in telephones until the 1980's (and in some parts of the world they are still in use!). Hughes's theory as to how the microphone worked was that it was a surface effect due to the number of points in contact that varied in sympathy with the sound waves.

Hughes was a man of short stature, blue eyes deeply set under bushy eyebrows, flowing chevelure and walrus moustache. He was mild mannered, independent, sometimes stubborn, but genial and sympathetic. He was said to be always full of interesting experiences and of a light heartedness that made him excellent company. However at times he became a catalyst (or as some viewed it a lightning rod) for stimulating great debates within the scientific community, either on the theory of electrical phenomena or on his experimental results.

One of these instances came about with his discovery of the carbon microphone when he crossed swords with Thomas Edison. Edison believed he had invented the carbon microphone first and suspected one of the English government officials (William Preece), whom he had confided in, of leaking his secrets to Hughes. Hughes's decision to give away his invention freely to the world only further infuriated Edison, who intended to capitalize on this invention. Unfortunately, the "Wizard of Menlo Park", as Edison was known, had misunderstood the circumstances, and before checking and discussing with Hughes, or others that he was accusing, immediately took the dispute public in the newspapers. Therefore, an affair that could have been settled amiably

became a nasty war of words and accusations and counter accusations dragged out in the major technical journals and newspapers.

The dispute drew in the who's who of the scientific world, who waded in with their opinions and in support of their respective champion. The dispute eventually became nationalistic pitting the much larger scientific community of Europe against the smaller one of America. In the end, it was concluded that each had carried out their research independently and there had been no leaks. Hughes, having discovered in the microphone a device that had wide applications and Edison having concentrated specifically on the telephone transmitter. The chief scientist of the day in Britain, Sir William Thomson (Lord Kelvin) scolded Edison in the press over the affair and requested an apology from him for his unfounded accusations - Edison never did reply.

## THE INDUCTION BALANCE

Hughes recovered from the assault on his character, and in Europe, at any rate, he was lauded as the inventor of the microphone. The months of publicity had also elevated his name and status amongst the scientific community and the public. Hughes was next to turn his attention to a vexing problem, that of interference on telegraph wires. He had investigated the problems some years earlier while in France, and now the problem had taken on a new urgency with the introduction of the telephone. When the telephone was introduced, it made use of the single iron wire telegraph lines with an earth return, which was far from ideal. In the cities, the



telegraph caused significant interference for the telephone. Hughes set to work experimenting to understand the nature of the interference.

He set up a simulation in his lab of telegraph lines using wire coils to simulate lines of many miles in length and whose proximity could be varied to simulate the coupling. The outcome of the research was a solution for suppression of interference on multiple lines. The research also yielded the use of twisted wire pairs for telephone use and the use of shielded wire (coax). However, it would be many years before these techniques were put into use.<sup>20</sup>

In doing research with the induction coils that canceled out unwanted signals, he noticed that they were also sensitive to the presence of small amounts of metal. This led him to further experiments, resulting in the Induction Balance.<sup>21</sup> The device con-

sisted of four coils (two primary and two secondary) that were connected and carefully positioned so as to be in opposition to each other, so that when the primary was excited by a pulsed source and the secondary connected to a telephone receiver no sound could be heard. Hughes' pulsed source consisting of his microphone in close proximity to a loud ticking clock and the newfound sensitive detector, the "telephone receiver", turned the arrangement into a useful device.<sup>22</sup> If a small piece of metal was introduced into one set of coils the arrangement would become unbalanced and this could be detected in the receiver. ( Fig 8.)

The apparatus was extremely sensitive, being able to detect minute quantities of metal or alternatively was able to compare two like samples. The device found use at the Royal Mint to compare and check metal alloys used for coinage. Whilst the device proved

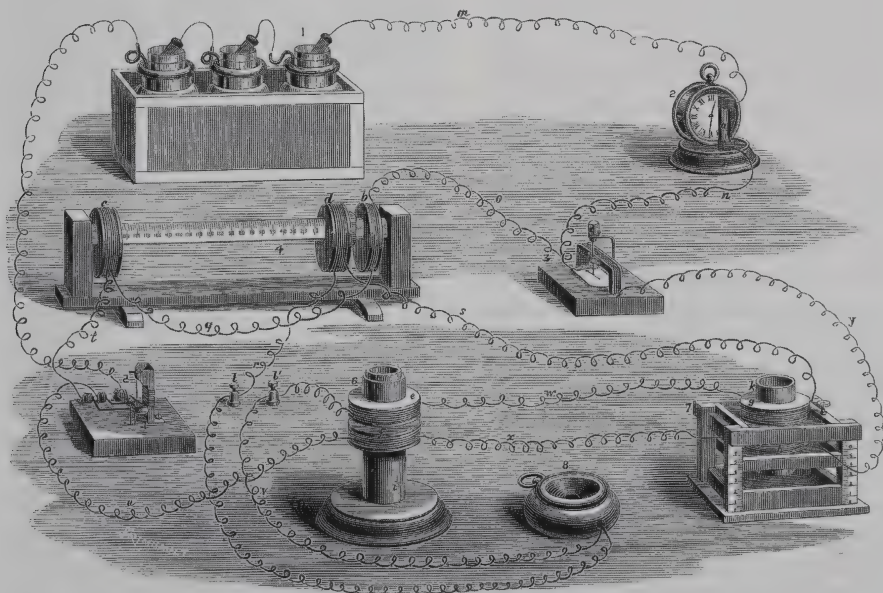


Fig. 8. Hughes' Induction Balance and Sonometer

useful, there was still much to be understood about induction in metals, such as eddy currents, that were still unknown. Hughes' induction balance was the forerunner of today's "metal detector", now in wide use as a recreation device to look for buried treasure on the shore, in the process industry for detecting metal fragments in fluids, etc., and standard equipment at security checkpoints. Out of this research came a number of interesting off shoots.

One was a device he called a "Sonometer" that consisted of two coils mounted on either end of a graduated ruler. A third coil was mounted between these coils and was free to slide along the ruler. (see fig. 8). The end coils wired in opposition and were excited by the pulsed source. The sliding coil was connected to the telephone receiver. When the sliding coil was at midpoint along the ruler it experienced a null and no sound could be heard in the receiver. Sliding the coil towards one end increased the volume of the signal whose value could be correlated with the scale on the ruler. Hughes used this in conjunction with his induction balance as a means of making relative measurements. This was done by switching the telephone receiver back and forth between the induction balance and the sonometer until the relative volume of the two signals was judged the same. The reading was then taken off the ruler scale. The sonometer was also adopted by the medical profession and used extensively for testing hearing.

One of the more famous uses of Hughes' induction balance was Alexander Graham Bell's application of it in 1881 in the desperate attempt to try to determine where the bullet had lodged in President

Garfield, while he clung to life after being shot by an assassin. Bell consulted with Hughes but despite his best efforts, he was unable to locate it before President Garfield succumbed.

## WIRELESS DISCOVERY IN 1879?

Hughes was a great experimenter, and nowhere is it more apparent than when reading his notebooks.<sup>23</sup> Here the experiments come alive as the reader follows the scrawled handwriting from one page to the next. He was methodical and innovative, his peers saw him as a gifted experimenter as he seemed to have the ability to be able to hit on the right approach or combination of experiments that brought about success. His next discovery was probably his most innovative, but was to be a bittersweet story. His experimentation, resulting in the discovery of wireless, became virtually hidden for many years and his discoveries only became known in the waning years of his life. His experiments took place a number of years before Hertz and Marconi. History finally credited him with the discovery but over time it has slipped off the pages of history.

It all came about when Hughes was experimenting with his induction balance in the fall of 1879. He had started with a primary circuit consisting of a set of coils being pulsed from a battery by clockwork driven contactor. A secondary circuit consisted of a second set of coils inductively coupled to the first that were connected to a telephone receiver. When he rearranged this configuration, it gave him some unexpected results – in that he could still hear the make and break sig-

nal even when he thought he shouldn't. He suspected it was either due to an effect called the "extra current" (the current induced in an inductor when its magnetic field rises or collapses) or the breakdown in the insulation of one of the coils.

However, it turned out to be a loose connection between some wires. As the effect was puzzling, he pursued it, substituting one loose connection for another by inserting one of his loose connection microphonic joints from his microphone experiments. Still he continued to hear the signal in his telephone receiver. The mystery grew as he separated the primary circuit from the secondary by some distance and only connected by a single wire. He was struggling to understand how the signal could be heard with a circuit that was apparently incomplete - that is an open circuit.

He also experimented by removing the coils from the secondary part of the circuit and he could still hear the signal of the make and break in the telephone receiver. He then proceeded to the next inevitable step. He cut the connecting wire and still could hear the signal. He was baffled and rationalized that the signal must be traveling between the two circuits by "conduction" through the building structure. Initially the gap between the two circuits was only six feet. He then moved the receiver (although Hughes didn't use this term until much later) to the next room, and eventually some 60 feet of separation.

What was significant was that he was detecting the make and break with a receiver in which the secondary coils had been removed and consisted only of a telephone receiver in parallel with his microphonic joint. In these experi-

ments, he had started to ground one side of the circuit to either a gas pipe or water pipe (not unusual for a telegraph engineer). He also took the receiver a couple of floors down in his house to his basement where he could still plainly hear. He grounded the receiver to one of the pipes and believed the signal grew louder and put this down to the fact that the different metals were creating a battery effect. This led him to add a small low voltage battery to the receiver circuit with the microphonic joint.

To solve the mystery as to how signals were traveling between the transmitter and receiver he suspended the receiver by non-conducting cords from the ceiling and concluded that it could no longer be conduction through the house structure but the signal was coming through the ether (the air was considered to be more complex in the Victorian period). He concluded it was traveling by lines of force and the more of them he intercepted the louder he could hear the signal. It is surmised he came to this conclusion by comparing it to the invisible lines of force that surround a magnet or current carrying conductor.

Although he continued to call the device a microphonic joint it had become a detector and through extensive experimentation it had taken on a much different form and characteristics. His experiments revolved around trying to improve this device so that he could hear signals louder. He settled finally on two configurations for the detector: one of oxidized copper wires looped together, and the other a steel needle resting on a piece of coke. He encapsulated these detectors into small bottles for protection. In arriving at these he had also tried



many other forms of his microphone components with mixed results such as a glass tube filled with metal filings and iron wires dipped into mercury.

Hughes next took his receiver and walked out into the street and continued walking, and was still able to hear the signal until by 500 yards it had faded away. This was an embryonic “wireless” experiment but the phenomenon of creating the invisible electromagnetic waves and being able to detect their presence was unknown at the time. It is interesting to note that his previous inventions of the microphone and induction balance and his use of the telephone receiver were all necessary prerequisites and essential ingredients leading up to this discovery. (Fig 9).

Hughes was a scientist of the school that was called “the practical men” whereby discoveries were made by experimenting. Any supporting theory or formula was a rarity and quite often regarded as suspect by these “practical men”. However there was a new breed of scientist surfacing. These were mathematicians and

physicists who tackled problems first from a theoretical point of view. One such person was James Clerk Maxwell, a brilliant Scottish mathematician and physicist working at Cambridge University. In the 1870’s he predicted mathematically the theory of electromagnetic radiation, (the basis of wireless signals), a theory he amazingly developed without any experimental evidence or indication of how electromagnetic waves might be produced or detected. Looking back, this was profound, and its impact wasn’t fully understood at the time.

Meanwhile, just over 50 miles away in London, Hughes had experimentally demonstrated just what Maxwell had predicted and had produced electromagnetic waves and detected them – which was the experimental validation of his theory and the missing link. Unfortunately, fate was to intervene, Maxwell died young in 1879, the year Hughes made his discoveries, and Hughes, who was not a mathematician, would not have been able to decipher Maxwell’s complex mathematical equations.

Hughes, however, was so ex-

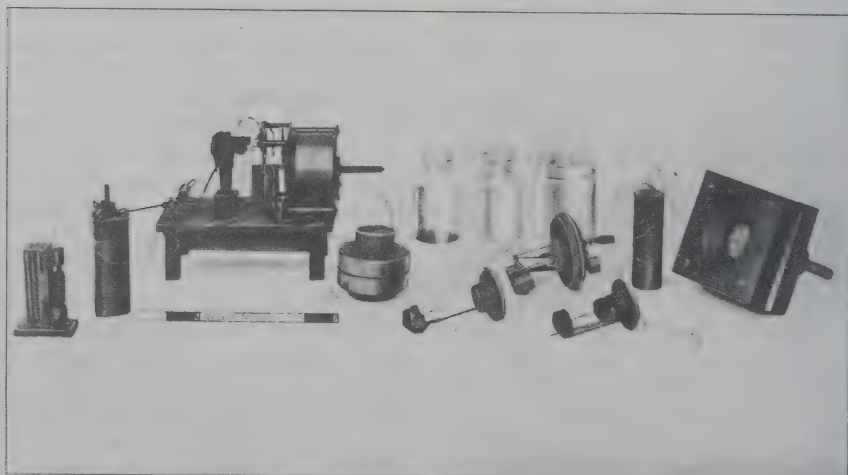


Fig. 9. Hughes wireless components.

cited by what he had discovered that he repeated his experiments in 1880 to important members of the Royal Society, the premier scientific organization of the day that included Professor Gabriel Stokes. Stokes was also from Cambridge University and a mathematician who knew Maxwell and was aware of his work. Could he possibly make the connection between Maxwell's theories and Hughes experiments? However, it all unraveled, and what could have been the start to a brilliant discovery, possibly Hughes greatest, and the verification of Maxwell's work was stopped dead. Stokes observed the experiment and stated that it was not a new phenomenon and could be explained by already known facts of electromagnetic induction. He failed to make any connection with Maxwell's theories or recognize it as a new phenomenon. It was just like pricking a balloon, dashing Hughes's hopes and swaying the opinion of the other observers in the process. Thus, a promising discovery, instead of being encouraged, was scuttled. Hughes was frustrated and angry after the meeting. For some reason, though, Hughes did not appear to have talked about his theory of the signals being transmitted by lines of force, but talked about conduction, probably confusing the issue.

Hughes was, however, reluctant to cross Professor Stokes, a man whose opinion was so widely influential. It is unfortunate that these experiments were not disclosed to scientists with a better understanding such as Oliver Lodge or George Francis FitzGerald. These two young scientists had become fascinated by Maxwell's work and could have perhaps grasped the significance

of Hughes experiments, and so could have advised him accordingly.

Hughes by this time had probably become aware that he was to be proposed for membership to the Royal Society, a status that he deeply sought. This provided a further reason not to strike any discord with Stokes or the other members of the Royal Society for fear of jeopardizing his election. Had Hughes' work been recognized at the time it would have pre-dated Hertz by nearly a decade and Marconi by two decades.

As it was, his wireless experiments were not to come to the attention of the general scientific community for another twenty years when Sir William Crookes made some remarks about witnessing some of Hughes wireless experiments many years earlier. The author J.J. Fahie, who was close to completing a book on the "History of Wireless Telegraphy 1839-1899", was, like many others taken completely unaware.<sup>24</sup> He immediately contacted Hughes to follow up on Crookes remarks. Hughes at first was reluctant to divulge the information, unwilling to upstage the work of Hertz and Marconi that had occurred in the intervening years. A generous gesture. Fahie was eventually successful in persuading Hughes to relate to him the experiments and included them into his book. They were also recounted in a number of technical journals.

Hughes did become a "Fellow" of the prestigious Royal Society in 1880 and continued research and experimentation. He had always been interested in the molecular aspect of materials and magnetic properties of metals and it is to this that he next turned his attention. During the early 1880's, he pre-

sented many papers on such topics as “Molecular Rigidity of Tempered Steel”, and “The Cause of Evident Magnetism in Iron, Steel, and other magnetic Metals”. He, like other scientists, was deeply interested in what magnetism was. He presented papers on “Molecular Magnetism” and “Theory of Magnetism based upon New Experimental Researches”. During the course of the experiments, he devised a new instrument called a “Magnetic Balance” that enabled magnetic strengths to be measured.<sup>25</sup>

It was during this period in the 1880s that it seems Hughes finally managed to find time to marry his long time friend from Paris - Anna Chadbourne in 1882. She was an accomplished artist, a resident of Paris and also an American citizen. She had been widowed a number of years earlier when her husband, Charles Morey, a promoter of Goodyear’s vulcanizing rubber process, was unfortunately, due to a misunderstanding, put in debtors prison, where he was accidentally and tragically shot by a prison guard.<sup>26</sup>

For Hughes his wife was a great supporter of his work and a great help with the many social requirements and engagements of the various societies that he belonged to. It is due to his wife that we have some documentation on his life, as it was she who made copies of his letters and made small notes of his memories of his early life.

In 1886, Hughes was elected President of the Society of Telegraph Engineers (later to become the Institute of Electrical Engineers). Ducking the usual formal acceptance speech Hughes decided instead to share with the society some of his resent researches. The subject was: “The Self Inductance of an Electric

Current in Relation to the Nature and Form of its Conductor”.<sup>27</sup> He was aware that he had obtained some unexplained results and hoped that by sharing them with the members of the society it would result in some discussion and possible explanation which he certainly got. He probably wasn’t ready for the torrent of comments and depth of discussion that followed.

The experiments he presented had been conducted to investigate the interference on telegraph lines during the transient switching period such that occur with the leading and falling edges of pulses. It was an area that had received little attention, but was believed to be the cause of many of the problems that still plagued the industry. The results he presented stimulated an interesting outcome. Hughes like many of the members of the Society was one of what were called the practical men – those who had come about their knowledge via hands-on experimentation and years of experience. There were also members of the society who were academics and who had risen through their university training. They were, however, in the minority and were viewed with suspicion by the practical men, whose attitude was, if they hadn’t been “field tested”, how could they have anywhere near the knowledge of the practical men.

There was also the matter of terminology that led to miscommunication between the practical men and the theoreticians. Standardization of electrical terms was still in its infancy and it was not uncommon therefore for terms to be invented, especially by the practical men.

When Hughes presented his experiments and results they were



totally contrary to what the academics would have expected. This time they couldn't sit by and not challenge them. Lord Rayleigh became their spokesman and believed that Hughes's equipment was in fact not measuring what he believed it was.<sup>28</sup> Hughes had made his experiments based on a modification of his induction balance. Rayleigh was an excellent spokesman working with Hughes in a non combative manner to delve into his experiments and ending up devoting a year of his time to help sort it all out. The dissection of Hughes experiments and discussion in the technical journals ranged far and wide.

It turned out that Hughes experimental apparatus was flawed and thus the majority of his results were incorrect. Nevertheless, there was one set of experiments in which the academics saw some merit. On the recommendation of Rayleigh and others Hughes modified his apparatus and reran the experiments, this time obtaining less controversial results. However in the one area that had previously shown some merit, Hughes obtained additional important data.

For one scientist though, the whole episode had proved too much. This was the reclusive scientist Oliver Heaviside who never ventured out to any of the scientific meetings but communicated via letters and through the technical journals.<sup>29</sup> He had been publishing highly mathematical papers for some time in the journal *The Electrician* which had drawn little attention. Now he saw in Hughes' experiments some results that appeared to verify a mathematical analysis he had made the previous year. Not wanting to lose out on the credit he also joined the discussion. It turned out what

Hughes had demonstrated was an increase in a conductor's resistance with an increase in a signal's frequency. This was to become known later as the skin effect, whereby the higher the frequency the more the current crowded to the surface of the conductor resulting in an increasing resistance. At RF frequencies the current flows only in the skin of the conductor. Oliver Heaviside had mathematically proven this, which he called the thick wire effect and took Hughes' experiments as the practical verification of his formula.

For the theoreticians it was verification of their worth, that theory could predict a practical outcome and was starting to explain many of the mysteries that surrounded electricity and magnetism. Oliver Heaviside's work finally started to get the recognition it deserved. Hughes' experiments had finally provided the opportunity for him to shine and it was to be the turning point from where the theoreticians or the "new school" as Hughes called them, started to come into prominence and the old school practical men's influence started to fade.

Hughes continued to be recognized for his scientific contributions and in 1885 was awarded the Royal Medal from the Royal Society. He was also active with the Royal Institution becoming their Vice President in 1891. The Royal Institution had had such prestigious past presidents as Sir Humphrey Davy and his protégé Michael Faraday.

Hughes realized as time went on that his breakthrough invention period was probably over. He still continued to receive money from the success of his telegraph systems and he had judiciously invested it providing him with a

sound financial base. He and his wife, while enjoying a comfortable lifestyle, were not extravagant, and elected to live in an apartment on Great Portland Street and later around the corner in Langham Street. They enjoyed an extended tour of Europe each summer.

Hughes started to redirect his energies in other ways such as helping younger prospective engineers and scientists on their way. He was keen on seeing them get ahead with an education especially if they showed initiative in helping themselves. To be in a better position to promote and influence them, he became associated with the London Polytechnic School of Engineering and became their President. He took the job seriously and often stayed up late at night writing letters of encouragement and advice to students, giving them hints and opinions on their inventions or experiments.

He continued to be recognized for his work and was awarded the Albert Medal in 1897. A medal that Faraday, William Thomson (Lord Kelvin), Louis Pasteur and Sir Joseph Lister had previously received. As the century came to a close his health started to deteriorate and he barely saw the New Year in as he died on 22 January 1900 and was laid to rest in Highgate cemetery.

Always generous in life he was also generous after his death. Hughes' estate was valued at £472,704, (\$2,268,979).<sup>30</sup> Hughes was in the minority, being a self-made scientist who actually was a financial success. After providing for his wife and relatives he left a substantial amount of his wealth to the London hospitals in the form of "The David Edward Hughes Hospital Fund". This fund is still in opera-

tion today and still providing benefits to the hospitals.

To the professional organizations he left sums of money to establish medals, awarded annually in recognition of original scientific research. The Hughes medal continues to be awarded annually at the Royal Society and has been awarded to such notables as Stephen Hawking in 1976 and Alexander Graham Bell in 1913, as well as: Max Born, Robert Watson Watt (Radar), H. Geiger, Neils Bohr, Edward Appleton, Ambrose Fleming and Augusto Righi.

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  - <sup>20</sup> Hughes D.E. *Experimental Researches into means of Preventing induction upon Lateral Lines*. Society of Telegraph Engineers, March 12. 1879.
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  - <sup>30</sup> The exchange rate in 1900 was £1=\$4.8. It is difficult to make a comparison of monetary values over such a long time span but this was probably equivalent to \$20million in today's value.

This article was peer-reviewed.



## PHOTO CREDITS

Fig. 1 DEH Papers

Fig. 2 DEH Papers

Fig. 3 American Telegraph,  
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Fig. 4 I. Hughes

Fig. 5 - Smithsonian Museum,  
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Fig. 6 - Archive de France  
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Fig. 7 *American Inventor*, June  
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Fig. 9 - Sciences Museum, Lon-  
don

## ABOUT THE AUTHOR

**Ivor Hughes** spent his early years in the UK and has had a life long fascination with electronics. He initially served as an apprentice in the telephone industry where he received a great practical education that ranged from the basic telephone through to RF group carrier systems. After receiving his BSEE he went into R & D, working on Navigation and Attack electronic systems for aircraft for the British Aircraft Corporation. In the late 1960's, he was recruited by United Technologies in the United States to work in their Electronic Avionics Division as a systems engineer. Here he was involved in electronic systems design of jet engine propulsion controls and flight controls.

In the 1970's, he moved employment to Goodrich Aerospace to work as a system designer of avionics systems. As the work also included flight testing in helicop-

ters it was both an exhilarating and exciting experience on which to end a career.

During his employment, Ivor was awarded a number of patents. His career spanned the wide technology transition that started with analog circuits through the mixed analog/digital period into the digital and software driven designs of today.

Since his retirement, he has had more time to devote to experimenting and researching the history of technology of telegraph and early wireless. For the last few years, he has focused in on his



Ivor Hughes

namesake David Edward Hughes. The results of this research are to be published in book form next year (2010) as a biography of Hughes.

## AWA Review

# How Dunwoody's Chunk of 'Coal' Saved both de Forest and Marconi

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## ABSTRACT

The success of wireless telegraphy pioneers Marconi and de Forest owes much to the invention in 1906 of a simple, reliable detector of wireless signals by a then-retired Army General, Henry H.C. Dunwoody. He showed that carborundum could act as a stable and sensitive detector, permitting the wireless operators of the day to hear even transatlantic signals. The carborundum detector got de Forest out from under what would otherwise have been a company-killing injunction obtained by Fessenden, whose electrolytic detector patent de Forest infringed. It also facilitated the development of a noise cancelling circuit essential to Marconi's long wave transatlantic success as early as 1907 and up to the vacuum tube era. For a decade it was state-of-the-art, stabilizing the circuits and operations of wireless telegraphy and thus fostering new directions of innovation.



Fig. 1. This undated photograph of Brigadier General H. H. C. Dunwoody, circa 1904, shows him in the dress uniform of the era. [1] The yellow sash is a decoration for bravery in the Spanish American War in Cuba.

United States Army Brigadier General Henry H.C. Dunwoody is little known today. Yet he invented the crystal detector of wireless spark signals about March, 1906. In the early twentieth century his device came to be known as the "heart of radio." Dunwoody's crystal detector saved Lee de Forest from a federal injunction sued out by Reginald Fessenden, and then saved the Marconi Company from the long-wave static that challenged the first transatlantic circuit from Ireland to Nova Scotia in 1907 and subsequent years.

General Dunwoody had a distinguished military career, serving in Cuba during the

Spanish American War, and living to 90. He was widely honored for his leadership of the U.S. Weather Bureau in the 1880s. In 1883 he wrote a book *Weather Proverbs* (still available) compiling folk wisdom about weather in order to make better predictions. The Arlington National Cemetery [2] summarizes his military career:

"Henry Harrison Chase Dunwoody of Ohio [:] Appointed from Iowa, Cadet, United States Military Academy, 1 September 1862[:] Second Lieutenant, 4th U. S. Artillery, 18 June 1866... Major, Signal Corps, 18 December 1890[:] Lieutenant Colonel, 15 March 1897[:] Colonel, Chief Signal Officer of U. S. Volunteers, 20 May 1898 [Cuba][:] Colonel, Signal Officer, U. S. Army, 8 July 1898 [retired as a Brigadier General, 1904][:]" Died 1 January 1933."

West Point was a leading engineering school of the day; Dunwoody graduated 19th in his class according to its records. After he retired from the Army and after a brief interlude with the de Forest enterprise, he manufactured armaments in several companies, part of the original military-industrial complex. Arlington Cemetery posts [2] a newspaper feature article (and obituary) telling of his life and success as a meteorologist as well as the inventor of what it called the Heart of Radio:

"Fairfield Weekly Led-

ger-Journal August 30, 1928. Inventor of 'Heart of Radio' Is a Former Fairfield Citizen. General H. H. C. Dunwoody went from here to West Point; was in Charge of Weather Forecasting for the Weather Bureau for Years, and headed the Signal Corps of the American Army in the Cuban Campaign. Old timers remember Gen. Henry H. C. Dunwoody when he was a boy in school here

No. 837,616.

PATENTED DEC. 4, 1906.

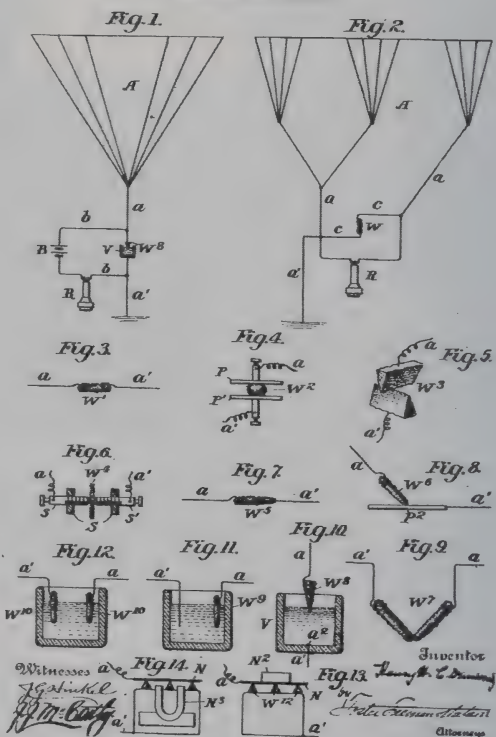
H. H. C. DUNWOODY.  
WIRELESS TELEGRAPH SYSTEM.  
APPLICATION FILED MAR. 21, 1904.

Fig. 2. Dunwoody 1906 carborundum detector patent, number 857616. Note that circuit figure one uses DC bias. Marconi used this as a basis for his detector circuit. Note figure four displays the carborundum between two steel plates, which came to be the usual configuration because of its mechanical stability. One of the patent claims is that the detector will not burn out when in proximity to a transmitter, an important advantage shipboard as well as in shore-side installations with co-located receiver and transmitter equipment. The patent omits tuning circuits.



and up to all the pranks of a lively lad. He was born in Highland County, Ohio, Oct. 23, 1842, and so is in his 86th year. He now lives at Ovid, New York."

Gen. Dunwoody employed carborundum (which he called crystalline silicid of carbon), under mechanical pressure and electromotive pressure (i.e., with a bias voltage) to detect wireless telegraphy signals. [3] His patent appears in Fig. 2.

The substance Dunwoody worked with is now known as silicon carbide. Nineteenth century chemist Edward Acheson accidentally created this artificial compound in his search for a way to make diamonds. [4] Dunwoody discovered its semiconductor properties. It was for this discovery that he was later said to have invented "the heart of radio." As this note will show, his invention sustained the success of the two most important early wireless telegraphy companies.

Prior to Dunwoody's invention, Chandra Bose, the Indian physicist, discovered the rectifying properties of galena (lead sulfide) and patented a detector of Hertzian waves (microwaves) that employed these and related properties. (The priorities of Bose are widely discussed in recent literature [5]). Karl Ferdinand Braun also developed a rectifying crystal diode at least as early as 1898.

A little after Dunwoody, another wireless experimenter, Greenleaf Whittier Pickard, invented a complete wireless receiving system (a "crystal set" that was tunable) in August, 1906, using silicon alone and what came to be known as the "cat's whisker" interface. His patent [6] appears in Fig. 3.

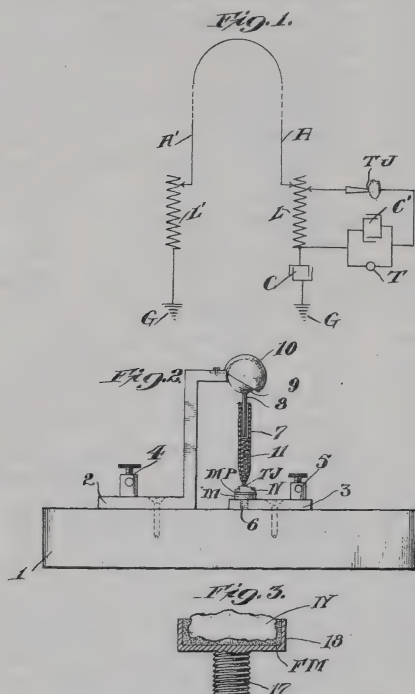
Before the crystal detectors, commercial, naval and amateur

wireless signals were detected, i.e., made hearable or readable, by use of the Edouard Branley filings coherer, the John Ambrose Fleming valve vacuum tube diode, the Marconi magnetic detector (colloquially known as the "maggie"), and by electrolytic processes (primarily discovered by Canadian Reginald Aubrey Fessenden).

Lee de Forest employed General Dunwoody in 1906 in New York, after he retired as the Army's Signal Officer. In his autobiography *Father of Radio*, [7] de Forest says of the carborundum device that it was: "... a simple rectifier which had been discovered by General Dunwoody, former chief Signal Officer, and now vice-president of the company", i.e., the de Forest Wireless Telegraph Company, Inc. De Forest brags about how much better the carborundum detector is than the Marconi magnetic detector for "reading through interference or static." He delights in calling Marconi Company wireless operators "limey Sparks." He says that many a "limey Sparks," in order to effect better reception of Marconi stations' spark signals, took to "concealing about his person a small chunk of 'coal,' as the Dunwoodie [sic] carborundum was later called." [8]

The wireless companies of the day prohibited use of non-company devices, to avoid patent infringement claims. Hence the need for concealment. But a clever Sparks could substitute the better carborundum detector for a Marconi detector at sea, with no one the wiser.

At the time (and as always) de Forest was challenged by litigation. The Canadian wireless pioneer Fessenden in particular had sued de Forest about commercial use of an electrolytic detector that Fessenden had invented about



Attest:

James C. Smith  
J. Francis Alley

Inventor:

Greenleaf Muttien Pickard  
by Philip Harnsworth Atty

Fig. 3. Pickard "crystal set" patent of 1906, number 836581, employing silicon and what came to be called a "cat's whisker" contact with the silicon. Pickard claimed silicon as a wireless detector that did not require a bias voltage with the inconveniences of batteries and the like. His circuit isolates the detector and its tuning from stray capacitance and body proximity effects.

1903. De Forest in his autobiography goes on to say that the American De Forest Wireless Telegraph Company's directors had decided to use, at the company's stations, the Dunwoody carborundum detector. They in effect decided to forego de Forest's legally problematic "spade" electrolytic detector at issue with Fessenden. De Forest almost by accident no longer infringed

Fessenden's patent. De Forest gloated about the unhappy consequences for Fessenden's litigation of his directors' decision: "... happily for me as it later turned out." [9]

Dunwoody's invention of the carborundum detector thus saved de Forest's wireless enterprise. Fessenden had persuaded a court to issue an injunction against de Forest's use of any electrolytic detector. Dunwoody's detector worked as well and likely better, thus avoiding the sanctions of the injunction and permitting the company to remain in business. [10]

The judge's findings of fact and legal opinions in the detector injunction United States Circuit Court lawsuits were officially reported for their precedential and technical value, and may be found in the *Federal Reporter*

series of law reports.[11] De Forest's detector litigation reached an acme in the Audion and Fleming Valve dispute in 1916 [12]. This U.S. District Court judicial opinion discusses detectors, including Dunwoody's, at length.

One of the further advantages of the Dunwoody carborundum detector in marine service, beyond its sensitivity, was that it was mechanically very stable. This

was so because in its initial implementation two metal plates held the “coal” firmly. De Forest also concluded that its sensitivity was independent of the pressure of the contacts. [13] There is some data on relative sensitivities of early detectors. Carborundum appears to be about as good as the “maggie,” and not as good as silicon, see Fig. 4. [14]

The year 1906 was said at the time to have delivered the worst atmospheric static that the nascent wireless art had yet faced. Sunspots also peaked in 1906 - 07 [15] although no one at the time understood any connection with radio propagation or the auroral effects on it. Atmospheric static, especially on what we now call the long waves, was the bane of operators world-wide. In mastering this challenge, the carborundum detector played an important role in the development and success of Marconi’s international wireless circuits as early as 1907.

Marconi’s first working transatlantic circuit connected Clifden, Ireland with Glace Bay, Nova Scotia. A Nova Scotia archive [16] describes the role of Dunwoody’s

chunk of “coal” in this initial and successful first transatlantic circuit and some subsequent refinements:

“The construction of a receiving station in Louisbourg, Nova Scotia and a similar one in Letterfrack, Ireland in 1912-1913 represented the final phase of the establishment of the first transAtlantic radio communications service.

“The first Louisbourg detector was the carborundum detector, a rugged crystal detector invented by General H.C. Dunwoody of the U.S. Army. Marconi used a circuit called the “balanced detector,” in which two carborundum diodes were connected and electrically biased [sic: biased] in such a way that strong impulses produced by lightning discharges would tend to cancel out, whereas the weaker signal that the operator was trying to copy would be detected.”

The balanced carborundum crystal detector circuit appears to have been developed primarily by Marconi engineer H. J. Round. He later, on behalf of the Royal Signal Corps, worked with Major Edwin Howard Armstrong during

**Table 10.1** *Edelman’s comparison of detectors (1915/16)*  
[EDELMAN, P.: *Experimental wireless stations* (published by Edelman at Minneapolis, 1915/16) p.160]

TABLE OF DETECTORS—SENSITIVENESS

Type of detector	Energy required to operate in ergs. per dot.
Electrolytic . . . . .	0.003640–0.000400*
	0.007 §
Silicon . . . . .	0.000430–0.000450*
Magnetic hysteresis detector . . . . .	0.01 §
Hot-wire barretter . . . . .	0.08 §
Carborundum . . . . .	0.009000–0.014000*

\* According to Pickard.  
§ According to Fessenden.

Fig. 4. Table of relative sensitivities of wireless detectors from V.J. Phillips. [14]



the First World War. His work on the balanced detector circuit resulted in the Marconi Model 16 balanced Crystal Detector circa 1916.

Marconi engineer Elmer T. Bucher, in *Practical Wireless Telegraphy*, (1918) provides circuit details and a wealth of technical information on the carborundum detector. [17] See the graphical appendix to this note for Bucher's illustrations of the characteristic curve of carborundum, his analysis of its workings as a biased detector and two Marconi implementations of the steel and carborundum detector.

The Bucher schematic in Fig. 6. correlates with the Model 16. It worked by listening only on one crystal by holding the bias voltage on the other too low. The sharp input voltage of a static crash, however, moved both crystals high on their characteristic curves, and the resulting nearly equal detected voltages canceled each other out.

Note the top right buzzer circuit to enhance audibility of the detected almost-continuous-wave signals, known as undamped spark signals, which Marconi rotary spark transmitters

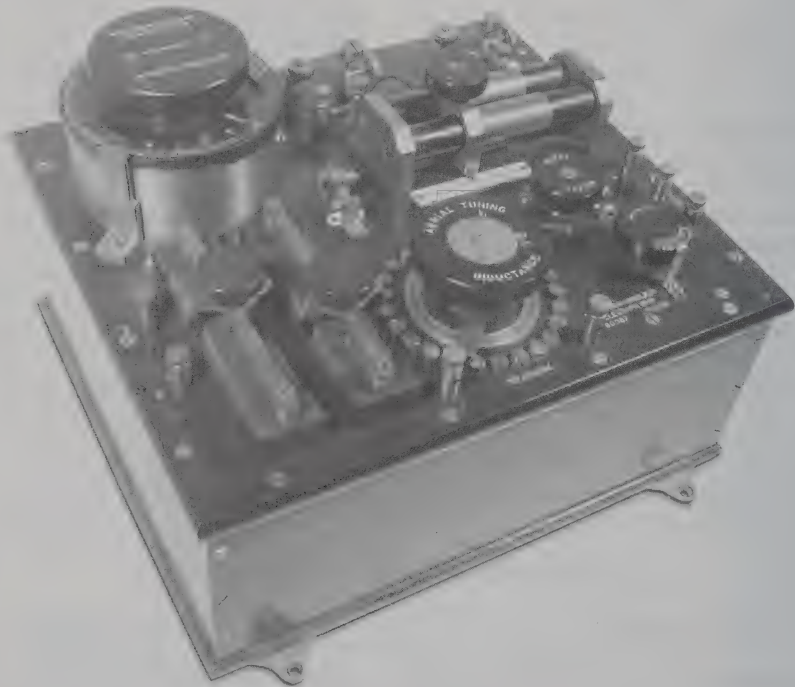


Fig. 5. The Marconi Model 16 balanced Crystal Detector circa 1916 at the Bellingham, Washington, American Museum of Radio and Electricity of John D. Jenkins. See: <http://www.sparkmuseum.com/MARCONI.htm>; copyrighted image used by permission. Note the two sliding linear rheostats at the bottom left, used to unbalance the bias voltages so that only one carborundum detector worked at a time (until a static crash activated both, cancelling the crash). Note also the adjustable tubular capacitor at the top right, which looks like the "Billi condenser," the last variable capacitance in the tuning circuit, the "secondary circuit," of the American Marconi Type 107A tuner, which also used carborundum as its primary detector.

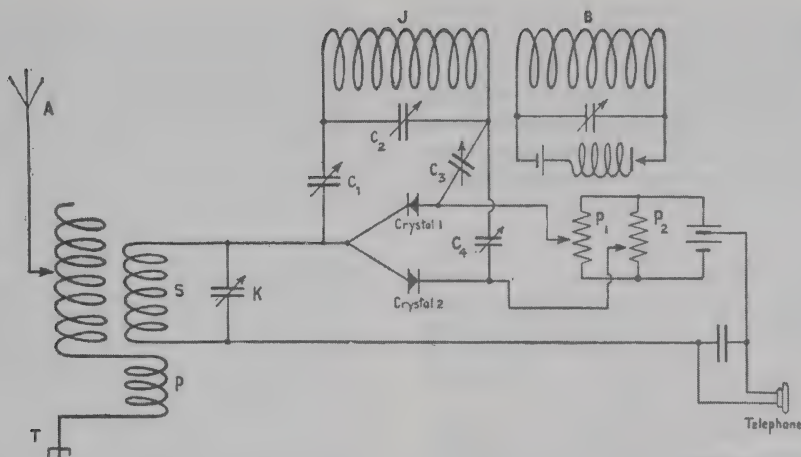


Fig. 300—Marconi's System for the Reception of Undamped Oscillations.

Fig. 6. Round's circuit for using two balanced carborundum detectors to minimize static in CW reception (Bucher's Fig. 300 B Marconi's System for the Reception of Undamped Oscillations) [17].

generated. Thus, by taking advantage of the characteristic curve of the biased carborundum rectifiers to cancel out strong signals (lightning crashes) but pass weaker signals of intelligence by one or the other detector, Marconi mastered atmospheric static. In the later development of this device, a tuned buzzer provided a heterodyne to make undamped (continuous wave) signals audible.

It is thus fair to say that Dunwoody's "coal" may well have saved the two most important wireless communications companies in the nascent days of the radio art, before the use of the vacuum tube. Dunwoody's detector had the advantages of mechanical reliability, as compared to galena or silicon detectors using "cat's whisker" interfaces. Nor did wireless operators have to find or reset a "sweet spot" especially after each transmission. Carborundum's performance when biased permitted the development of the noise cancelling circuit, for which other detectors were unsuitable. The manufac-

ture of carborundum presented no difficulty and it did not have to be mined and selected the way galena crystals, for example, did. Carborundum's sensitivity sufficed, especially in view of the tremendous power put out by the early commercial wireless transmitters, in the range of 300 kilowatts.

Dunwoody's carborundum detector bridged the receiving technology of the filings coherer of the early experimenters, including Marconi, and the later and soon dominant technology of the vacuum tube triode. Its availability, reliability and performance made it the detector of choice for nearly a decade, until the advent of Armstrong's regenerative circuit for de Forest's triode circa 1916.

In the absence of Dunwoody's discovery, both commercial and amateur wireless operations would no doubt have employed the several other minerals and detector technologies available, but at some cost especially in reliability. The great advantages of carborundum permitted the ener-

gies of innovation to focus on new circuits and techniques, and then on the quantum leap of vacuum tube technology for detection, amplification and oscillation, which provided the major electronic advances of the first half of the twentieth century.

## NOTES

1. The source of the photograph of then Col. Dunwoody is a page in the Archive of the New York Public Library, No. 1227290, NYPL Digital Gallery.
2. Arlington Cemetary - <http://www.arlingtoncemetery.net/hhdunwoody.htm> . This goes on: "Fairfield Ledger Tuesday, January 3, 1933 Former Fairfield Resident Passed Away Jan. 1. Brig. Gen. Harry [sic; Henry] Harrison Chase Dunwoody, 90, former chief signal officer of the U. S. Army, died at Interlaken, New York, Sunday according to word received here by friends." It is interesting to note General Dunwoody's grandson Harold Dunwoody served in combat in World War Two, Korea and Vietnam, retiring as a much decorated Brigadier General. His great- granddaughter, Ann Dunwoody, is now the U.S. Army's first woman four star general officer.
3. Dunwoody's patent is number 837616 dated December 4, 1906, filed March 23, 1906.
4. <http://www.reference.com/browse/all/crystal%20detector>.
5. See, e.g., Tapan K. Sarkar, et al., An Appreciation of J. C. Bose's Pioneering Work in Millimeter and Microwaves, in *History of Wireless* (2006), John Wiley & Sons, at pps. 291-310.
6. Pickard's patent is number 836581 dated November 20, 1906, filed August 30, 1906.
- 7, 8, 9. Lee de Forest, *Father of Radio*, self-published, 1949, at pps. 127, 195.
10. A. Douglas, "The Crystal Detector" *IEEE Spectrum* April

1981 p. 66.

11. National Electric S. Co. v. De Forest Wireless Tel. Co., 140 *F[ederal Reporter]* 449 (U.S. C.C.N.Y. 1905); National Electric Signaling Co. v. De Forest W. T. Co., 145 *F.* 354 (U.S. C.C.N.Y. 1906).
12. Marconi Wireless T. Co. v. De Forest Radio T. & T. Co., 236 *F.* 942 (U.S. D.C.N.Y. 1916).
13. Lee de Forest, in *Electrical World*, September 8, 1906 reported in D. McNicol, *Radio's Conquest of Space*, p. 125, -27 (Arno Reprint, 1974)).
14. V.J. Phillips, *Early Radio Wave Detectors*, (Science Museum, I.E.E., and Peter Perigrinus; London 1980) p. 213, Table 10.1.
15. E. W. Maunder [he of the Maunder Minimum episode of few sunspots], "The sun-spots of 1906 - II" in *The Observatory*, Vol. 29, p. 348-352 (1906) archived at: <http://adsabs.harvard.edu/full/1906Obs....29..348M>; see also for the intensity in 1907: <http://adsabs.harvard.edu/full/1907Obs....30..126M> .
16. The Official Research Site for the Fortress of Louisbourg (Nova Scotia, Canada) - <http://fortress.uccb.ns.ca/Marconi/marconi2.htm>.
17. Elmer T. Bucher, *Practical Wireless Telegraphy*, (1918) pp. 172, 286-87, 288ff and figs. 153 (a,b,c), 157, 157a, 158,163, 198, 199, 300.

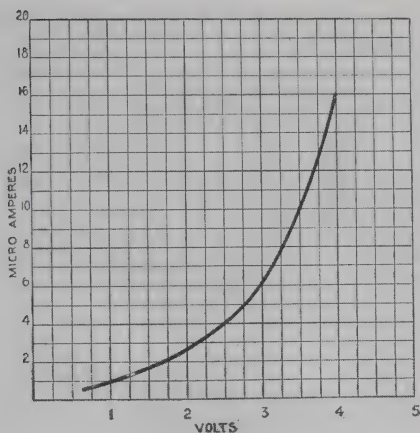
This article was peer reviewed.

## APPENDIX

The following illustrations from Bucher, *Practical Wireless Telegraphy* [17], provide graphical data on carborundum's performance as a detector and illustrate working Marconi Company detectors.

The so-called "characteristic curve" of carborundum (and other semi-conductors) is not linear, according to Bucher. (This is also true for other semi-conductors and vacuum tube diodes as well.) An





Bucher's characteristic curve for carborundum.

ordinary resistance curve is linear, i.e., the more voltage applied, the more current flows in an exactly proportional way: doubling the voltage doubles the current. A non-linear resistance on the other hand, permits a more than proportional current to flow as voltage increases. Bucher's curve for carborundum illustrates this characteristic.

Assume a bias voltage of two volts. An alternating radio frequency (RF) voltage comes to the detector from the antenna and tuning circuit. Assume it is two volts peak to peak. The negative (subtractive) one volt peak will decrease the bias current flowing from three micro-amperes to one micro-ampere, down the curve as it were. The positive, additive one volt peak will, however, have a greater effect. It will move the flow of current from three micro-amperes to six micro-amperes. The effect is all the greater higher up on the curve, at three volts bias for example. Thus the detector permits more current to flow in one direction when under the influence of the alternating radio frequency voltage.

Bucher then presents as his next stage of his explanation a diagram showing how the differential response to subtractive and additive parts of the RF input result in an average current flowing in only in one direction. He posits a bias voltage of three volts. The telephone receiver diaphragm integrates the

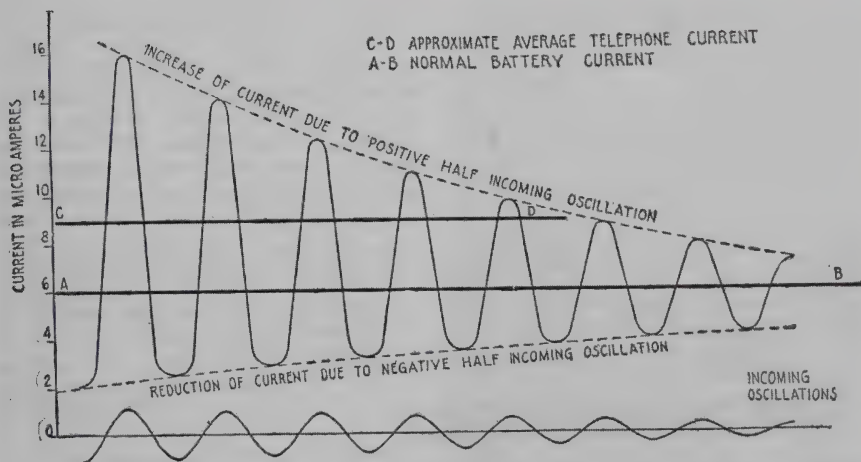


Fig. 157a.—Curves Showing the Fluctuations of the Local Battery Current flowing through the Carborundum Rectifier during the Reception of Signals.

Bucher's illustration of how the characteristics of biased carborundum make for asymmetrical if not one-way passage of RF and detection of it by way of differential current flows and mechanical integration by the telephone receiver diaphragm in response to them.

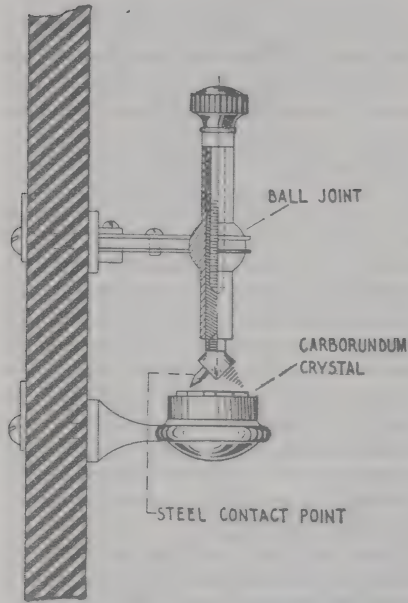


Fig. 158—Carborundum Detector Complete.

### Marconi vertical carborundum detector.

additive larger pulses into a virtual larger steady current. Bucher summarizes the effect this way: "... the added voltage due to the oscillating E.M.F. [electromotive force or voltage] being impressed on the crystal is greater than the subtracted voltage and that the final effect of this is an increase of current through the head telephone circuit over the duration of one wave train."

Marconi and de Forest had to reduce theory to practice. Bucher presents two illustrations of working carborundum detectors. The first is a vertical configuration, likely in use on a panel in shipboard installations. Bucher suggests use of a steel phonograph needle as the contact with carborundum in a holder, reminiscent of Pickard's holder for silicon as illustrated in his patent.

The second illustration also shows adaptive re-use. In 1904 Fleming had contributed the vacuum tube diode Fleming Valve

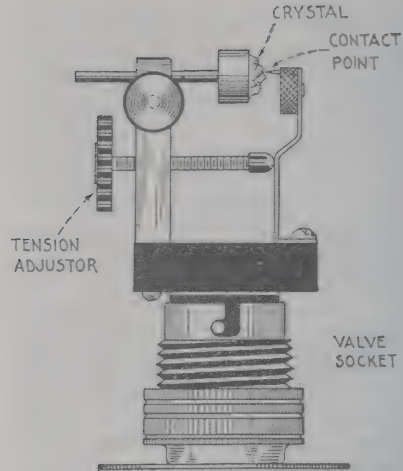


Fig. 163—Carborundum Crystal Holder to Fit Fleming Valve Socket.

American Marconi's substituted horizontal carborundum detector for a Fleming Valve.

to Marconi's operations. It was reliable but insensitive. According to Bucher, it was American Marconi Company engineers who cleverly affixed a horizontal carborundum detector to a screw base for the Fleming valve, permitting its substitution and use of the filament voltage as the bias. American Marconi had been De Forest Wireless, so perhaps that company's fondness for solid-state carborundum, even over the vacuum-state Fleming valve, carried over to this adaptation. It may also be the case that Fleming valves were hard to get and easy to break or burn out.

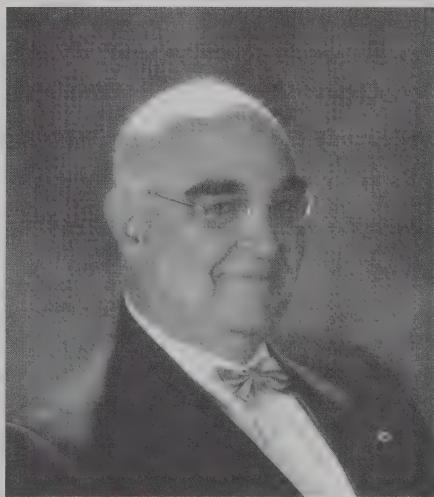
## ACKNOWLEDGEMENT

I am grateful to the distinguished Spanish antique radio collector and historian Salvador Munoz Gomariz for stimulating my interest in General Dunwoody; I am happy to have supplied for his use the photograph of Gen. Dunwoody and an earlier draft of this article. See <http://escibalofilms.blogspot.com/2009/01/henry-h-c-dunwoody.html>.

## ABOUT THE AUTHOR

**Bartholomew (Bart) Lee, K6VK, xKV6LEE**, holds an extra class amateur radio license. He has enjoyed radio and radio-related activities in many parts of the world, most recently in Singapore, Australasia, and the Papua New Guinea area. Radio history and technology have fascinated him since he made his first crystal-set with a razor blade and pencil lead detector more than 50 years ago. He is a widely published author on legal subjects, and most recently on the history of radio. He has written about radio in intelligence operations (from 1901 forward, including the CIA on Swan Island in the 1950s and 1960s), the history of wireless telegraphy, especially the work of Marconi and the independent developments on the U.S. West Coast, short wave radio and its history, radio ephemera including radio stamps, and radio in emergency and disaster response. Since 1989, he has made almost 20 annual presentations to the AWA Conference on his research interests, including the development of television in San Francisco in the 1920s. The AWA presented its Houck Award for Documentation to him in 2003 and the California Historical Radio Soci-

ety made its 'Doc' Herrold Award to him in 1991 in connection with the Electronics Museum of the Perham Foundation. In 2001, during the New York City disaster recovery operations following the "9/11" terrorist enormity, he served as the Red Cross deputy communications lead from September 12 to September 21. Bart has also served as the San Francisco Auxiliary Communications Service Liaison Officer, and as an ARRL ARES Emergency Coordinator. He presently serves as an ARRL Government Liaison and Volunteer Counsel, and as counsel emeritus to the California Historical Radio Society. Bart is a trial lawyer by trade, and a former Adjunct Professor in Law & Economics at a San Francisco University. He is a graduate of the University of Chicago Law School, and St. John's College. He invites correspondence at [KV6LEE@gmail.com](mailto:KV6LEE@gmail.com).



Bart Lee photo by Paula Carmody, taken in Indonesia; copyright Bart Lee 2009.





# From Coherers to Crystal Rectifiers

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## ABSTRACT

The story of how coherers became the dominant method of detecting radio waves in early wireless telegraphy systems and then transitioned to the rectifying crystal detector is fascinating. The story has never been fully and accurately recounted.

A number of questions are often asked: Who was the first to transmit and receive radio waves? What type of detector was used to receive these transmissions? Who first discovered the coherer and the first crystal detector, and when were they discovered? How many distinct modes of operation does a coherer have? Who gave the name “coherer” to Branly’s iron-filing tube? What are the differences between a coherer, a self-restoring coherer, and a crystal detector? Who first discovered the principle of rectification for the crystal detector? Who was the first to receive a patent for a crystal detector? Which detector is more sensitive, a good galena crystal detector or a good iron-filing coherer? The answers to these and other questions are likely to be of interest, if not a surprise, to most readers.

The story of how coherers became the dominant method of detecting radio waves in early wireless telegraphy systems and then transitioned to the rectifying crystal detector is fascinating, filled with many twists and turns resulting in lost opportunities for a number of early wireless pioneers. The development of the devices themselves has been chronicled many times, but the story has never been fully or accurately recounted. The account of this evolution—taken from original sources and embellished with data taken on both antique wireless detectors and mockups thereof—provides a fascinating story that will surprise and perhaps delight even the veteran historian.

To provide a point of departure for this account, a thumb-nail sketch of the major milestones in the development of the coherer and crystal detector is listed below in chronological order according to “conventional wisdom.”<sup>1</sup>

1. *Deviations from Ohm’s Law (1874)*: Ferdinand Braun<sup>2</sup> is generally credited as the first to measure deviations from Ohm’s law in materials that would later be recognized as semiconductors—materials which formed the basis of both coherers and crystal detectors. Many historians also credit Braun as the first to discover rectification by solid state devices in 1874. Braun claimed that he had experimented with radio detectors using crystalline materials as early as 1901, although he did not publish this claim until late 1906.

2. *Earliest Radio Wave Detectors (1887-9)*: Heinrich R. Hertz is credited with being the first to generate and detect electromagnetic waves in the laboratory in 1887 using a spark gap generator and a micrometer spark gap as the radio wave detector, and publishing his results in 1888. However, in 1879—twenty years before Hertz’s experiments—David Edward Hughes had generated electromagnetic waves with a spark discharge device and detected them both in the laboratory and at distances up to several hundred yards with sev-

eral different devices including a carbon-steel and/or a steel-carbon-copper contact device he characterized as a “microphonic joint” or simply as a “microphone.” While the results of his experiments were formally disclosed to members of the Royal Society at the time, they did not appear in print until 1899 due to an unfortunate set of circumstances.

3. *Early Non-Restoring Coherers (1889-1899)*: Édouard E. D. Branly is credited with discovering an iron-filing tube in 1890 whose resistance dramatically decreased when exposed to electromagnetic radiation. Upon hearing of Branly’s discovery, Sir Oliver Lodge claimed to have discovered a point-contact device in 1889 with a “double-knob” configuration whose resistance decreased when a Leyden jar was discharged directly across the knobs. In late 1893, Lodge recognized the potential for both devices as a sensitive detector of electromagnetic radiation, and as a result, he improved the iron filing device, added an automatic “tapper-back” to restore sensitivity after each pulse, and popularized it by demonstrating it to the Royal Society of London in 1894 and also to the British Association in Oxford. He also gave the name “coherer” to his point contact device, a name which was extended by the press to the iron-filing devices of Branly. During the period 1895-96, Guglielmo Marconi made other improvements to the iron filing coherer and, after applying for a patent on the device as part of wireless telegraphy system in 1896, used it as a detector in a practical wireless telegraph system—as did other companies such as Slaby-Arco and Telefunken.

4. *Self-Restoring Coherers (1897-1905)*: From 1897-1905, a

number of inventors discovered various types of self-restoring devices designated “auto-coherers,” a misnomer which implies that they would automatically cohere rather than de-cohere. Marconi popularized the self-restoring coherer by reporting the use of three such devices in his famous 1901 transatlantic communication experiment—the most familiar of the three being the Italian Navy Coherer gifted to him by Lt. Luigi Solari.

5. *The Swing to Aural Reception and the Adoption of the Crystal Detector: (1901-1906)*: While aural reception using self-restoring coherers as a detector and the telephone as the indicating device was discovered in 1879 by Hughes (and rediscovered by others beginning in 1897), the swing to aural reception by the major telegraph companies took place between 1901 and 1906 as the result of convergence of improvements in both detector and transmitter technologies. The swing to aural reception was led primarily by devices other than crystal detectors such as DeForest’s so-called “responder” introduced in 1901, Marconi’s magnetic detector introduced circa 1903-04, and Fessenden’s electrolytic detector introduced circa 1903, which was subsequently copied and used under the name “spade detector” by a DeForest Company, also in 1903. The crystal detector did not come into its own until 1906, the year that five distinctly different patents on crystal detectors were issued including the carborundum crystal detector which was adopted by the American DeForest Wireless Telegraph Company (later United Wireless) that year—events that have traditionally marked the beginning of the crystal detector era.



6. *Discovery of Rectification by the Crystal Detector* (1907): George W. Pierce is generally recognized as the first to use the designation "crystal rectifier," which appears in the title of his seminal paper "Crystal Rectifiers for Electric Currents and Electric Oscillations" dated July 1907. As a result of this paper, it became generally known that the point-contact self-restoring coherer was actually a rectifier, and thereafter it was known as a "crystal rectifier," or more generally, a crystal detector.

While the major milestones and the early pioneers associated with the development of coherers and crystal detectors are familiar, there are many interesting and unanswered questions—or questions answered incorrectly—about the actual roles of the various participants and the characteristics of the detection devices: Who was the first to transmit and receive radio waves? What type of detector was used to receive these transmissions? Who first discovered the coherer and when was it discovered? How many distinct modes of operation does a coherer have? Who gave the name "coherer" to Branly's iron-filing tube? What are the differences between a coherer, a self-restoring coherer, and a crystal detector? Who first discovered the crystal detector? When was the crystal detector discovered? Who first discovered the principle of rectification by the solid-state radio wave detector? Who was the first to receive a patent for a crystal detector? Which detector is more sensitive, a good galena crystal detector or a good iron-filing coherer? The answers to these and other questions are likely to be of interest, if not a surprise, to most readers.

The remainder of this article is divided into six main sections, one

corresponding to each of the major milestones identified above, followed by a summary. The answers to the questions posed above will be answered in the six sections, and concisely restated in the Summary.

## DEVIATIONS FROM OHM'S LAW (1874)

*Early Discoveries:* Ferdinand Braun is most often cited as the pioneer who, in 1874, first measured the deviation from Ohm's laws on contacts between natural metallic sulfides such as copper pyrite, iron pyrite, galenite, and tetrahedrite—materials later to be identified as semiconductors.<sup>3</sup> Braun reported on contacts with three distinctly different types of deviations from Ohm's law including: 1) resistances which varied with applied voltage of the same polarity, 2) resistances which were different for the same

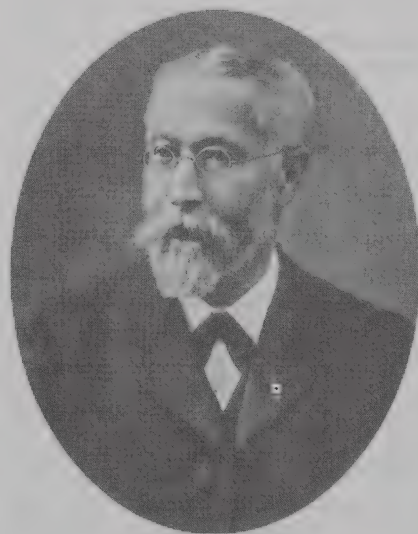


Fig. 1. Ferdinand Braun is generally credited as being the first to discover materials displaying deviations from Ohm's law in 1874, some of which were later used as crystal detectors in Telefunken wireless telegraphy systems.

applied voltage but with a reversal in polarity—later referred to by Braun as a “unipolar response,” and 3) resistances that depended on the duration of the applied voltage.

In the same issue of *Annalen der Physik* in which Braun’s paper appeared, Herman Herwig also reported observing that the resistance to currents in iron and steel rods varied according to the direction, intensity and duration of said current.<sup>4</sup> According to an abstract appearing in *Nature*,<sup>5</sup> Braun’s paper was actually a supplement to Herwig’s paper. Indeed, Braun stated that Herwig’s publication motivated him to report on the observations appearing in his paper. Despite Herwig’s independent discovery of deviations in Ohm’s law, and the fact that his paper appears to have motivated Braun to disclose his work in the same publication, Herwig is virtually never cited in reviews of seminal papers on early observations of deviations from Ohm’s law.

Arthur Schuster is also often cited for reporting a similar observation at essentially the same time as Braun, but in a circuit composed of copper wires joined together by means of binding screws.<sup>6</sup> However, Schuster noted only that: “*The current produced by an electromotive force in a circuit composed entirely of copper wires joined together by means of binding-screws may, under certain circumstances, be different from the current produced by the same electromotive force acting in the opposite direction.*” He said nothing about the resistance depending upon the *magnitude* of the EMF—only on the polarity—and provided only scant data. Schuster referred to this effect as “unilateral conductivity,” a term

equal in meaning to Braun’s unipolar response.

It is likely that Braun is most often cited as the first to discover this phenomenon rather than Herwig or Schuster, not only because his paper was the most complete, but also because he went on to publish three additional papers on deviations in Ohm’s law—the third of the four dated 1878 focusing on psilomelane, a crystalline substance that was used as a crystal detector in Telefunken wireless systems several decades later.<sup>7</sup> Not only that, he was the only one of the three to make significant contributions to wireless telegraphy—most notably for antenna design and tuning circuits circa 1898–90—for which he shared the Nobel Prize for Physics with Marconi in 1909.

*The Discovery of Rectification is Misstated:* Historians have occasionally overstated Braun’s discovery of deviations from Ohm’s law in 1874 by asserting that he also discovered rectification. However, there is no mention of rectification in his paper—or even a hint thereof—and no mention of applying alternating currents to the joints he tested. From the modern perspective, there seems to be a tacit assumption that rectification is synonymous with deviations in Ohm’s law. However, the *property* of deviations from Ohm’s law in imperfect joints such as those discovered by Braun in 1874 is distinct from rectification—an *effect* on alternating currents produced *under certain circumstances* by joints possessing this property. To illustrate this point, consider the I-V characteristics shown in Fig. 2 for two different devices displaying deviations in Ohm’s law, one which is symmetric (in the first and third quadrant) with regard to a rever-

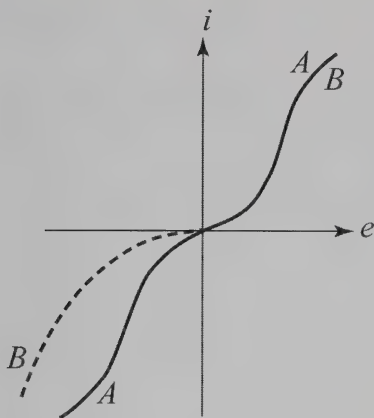


Fig. 2. The I-V characteristics for materials displaying deviations from ohms law are either symmetric (in the first and third quadrants) represented by the curve labeled "A," or asymmetric represented by the curve labeled "B."

sal of polarity of applied voltage and the other which is not. The I-V characteristics represent the relationship between the applied voltage and the current flowing through the device; the slope of the resulting curve,  $\Delta I/\Delta V$ , represents the conductivity—which, in a device which deviates from Ohm's law, is a function of the applied voltage.

When a sine-wave voltage is applied to the symmetric device, the current flow is equal and opposite in each half cycle and so there is no conversion of alternating current to direct current, and therefore no rectification. When a sine-wave voltage is applied to the asymmetric device, there is generally an asymmetry in the current flow, resulting in partial rectification which depends upon the degree of asymmetry and the magnitude of the applied voltage. For many imperfect joints, the asymmetry is very small when small signals typical of those

found in radio detectors are applied, and so there may still be little or no observable rectification for small signals even when applied to asymmetric devices. It is true that for either device, a d-c bias can be applied to move the operating point to place where the I-V curve is noticeably asymmetric about that point, resulting in partial rectification. However, this fact was not known at the time.

There is no evidence that Braun was aware of the rectification effect, at least for the class of solid state materials with which he experimented in 1874. A detailed reading of his seminal paper reveals that he never mentioned rectification, nor did he apply alternating currents in conjunction with these contacts. Many of the devices he tested had symmetric characteristics, and so he would not have observed rectification even if he had applied a-c signals to these joints—unless he had the foresight to apply just the right amount of d-c bias—in which case he may or may not have observed a small degree of rectification.

There is also no mention of rectification in any of his three papers which followed his paper of 1874, although there is one reference to a "valve effect" in his 1878 paper with regard to selenium. By valve effect, Braun was referring to an observation that selenium displayed a significant forward current but virtually no reverse current. However, there is no evidence in his papers that he realized this valve effect would convert alternating current to direct current. With regard to other types of imperfect contacts, he noted that he did not find a valve effect in "*contacts between metals and even tubes full of copper filings...*"<sup>8</sup>

The distinction between the



valve effect, per se, and rectification has been put into sharp focus in the history of the evolution of the thermionic valve, and is worth recalling here. Thomas Edison discovered the Edison Effect in a thermionic tube in 1875—later characterized as a thermionic valve—but found no practical application for it, nor did he recognize that it would rectify alternating currents. In fact, while everyone recognized that current would flow in one direction only (with a positive plate voltage) like a valve, no one recognized that it would rectify alternating current until 1897 when one John W. Howell revealed this fact to a meeting of the American Institute of Electrical Engineers (AIEE). The most telling revelation was made by attendee Dr. A. E. Kennelly, the principal electrical assistant to Edison himself from 1887 to 1894, during a discussion period following the presentation. He stated:<sup>9</sup>

*"It has long been known that the passage of a continuous current through a Geissler tube set up a series of pulsatory currents or discharges, which are capable of producing alternating currents in a separate circuit, through the intermediary of an alternating current transformer. So far as I know however, it has been pointed out for the first time in this paper, that an alternating current passing through an incandescent lamp giving the 'Edison Effect' is capable of producing in a branch circuit through a third wire in a lamp, continuous or at least unidirectional currents. Consequently it is interesting to observe that a vacuum tube, in the broadest sense of the term, is capable of supplying not only alternating currents from continuous cur-*

*rents, but also continuous currents from alternating currents."*

Indeed, this event was sufficiently notable that it appeared as a separate entry in the book *History of Wireless* by T. K. Sarkar under a section entitled "Some Crucial Events of the Nineteenth Century": "*American Engineer John W. Howell, an associate of Edison, pointed out at a meeting of AIEE that rectification takes place in an Edison Tube.*"<sup>10</sup>

There are two points to be made from the fact that it took over twenty years to realize that a vacuum tube displaying the valve effect could rectify alternating current: 1) the valve effect, per se, is not the same as rectification, and 2) even in the late nineteenth century—well after Braun noted a valve effect in selenium—rectification was not an obvious consequence of the valve effect. It is somewhat astonishing that after Fleming's discovery in 1904 that the thermionic valve rectified (i.e., detected) radio waves, it was still not recognized that solid state devices, which had also displayed a valve effect, might also rectify radio waves.

*Braun's Detector Experiments:* Quite apart from his measurements of deviations from Ohm's law, Braun became active in wireless telegraphy in 1898 beginning with his experiments with transmission of electromagnetic waves in the top layer of water using various wave generators involving sparking between spheres in 1898, which continued through the summer of 1899. In later half of 1899, he began with experiments in aerial telegraphy, first with the design of wireless transmitting antennas and then with tuned receiving circuits, for which he later shared the Nobel

Prize in physics with Marconi in 1909.

It was not until 1906 that he published two documents dealing with radio detectors. The first was a German patent on a psilomelane detector with a filing date of Feb. 18, 1906 which was issued on Oct. 22, 1906.<sup>11</sup> This patent contained a figure which clearly shows a relatively sophisticated device suitable for commercial work (see Fig. 3). Shortly thereafter, he published an article in the December 1906 issue of *Elektrotechnische Zeitschrift (ETZ)* in which he first summarized his earlier work on detecting deviations from ohm's law 1874-1883, followed by a disclosure of previously unpublished experiments with psilomelane detectors he claimed to have performed in May of 1901 and December of 1905.<sup>12</sup> This important paper contains the only known account of Braun's detector work, and is sufficiently important that it is reproduced here in English as Appendix A.<sup>13</sup> Here is what Braun had to say about his earlier detector experiments performed in 1901:

*"In May 1901, I performed some tests in the laboratory and found that indeed a telephone receiver which was connected into*

*a circuit consisting of psilomelane and other elements, provided clear and sharp sounds when small fast oscillations were fed into the circuit. The result was verified, and with surprisingly good success at that, at the stations for wireless telegraphy, which at that time was performed at the Straßburg Station of the Royal Prussian Airship Department under leadership of Captain von Sigsfeld."*

After describing details of some of the experimental results, he went on to describe his later efforts on detectors in 1905 as follows:

*"The best among the different materials tested proved again to be psilomelane. It is uniform and allows the use of larger electrodes. I repeated the laboratory observations at the end of December in Berlin at the Society for Wireless Telegraphy. There the substances served directly as wave indicators in receivers. The results obtained in Straßburg were confirmed, but the sensitivity was not as great as with a Schlömilch-cell. Mr. Schlömilch's continued efforts resulted in the removal of this last imperfection and brought the sensitivity to the level of the electrolytic wave indicator [the*

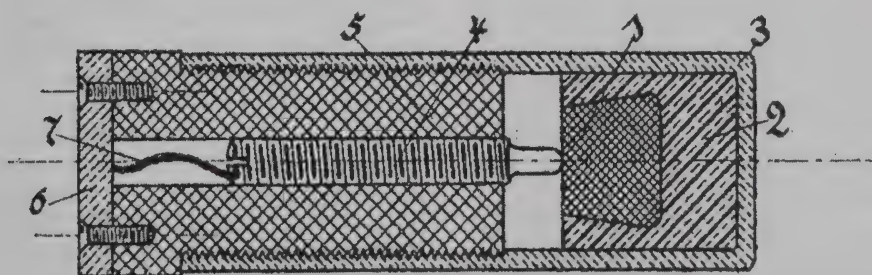


Fig. 3. Ferdinand Braun developed and patented a practical psilomelane crystal detector consisting of a threaded metal contact [4] capable of applying variable pressure against a crystal of psilomelane [1]. (F. Braun, German patent No. 178871)



Schlömilch-cell].”

The timing of Braun’s patent application for a psilomelane detector dated Feb. 18, 1906 clearly supports Braun’s contention that he performed experiments on detectors in December of 1905.

The only additional disclosure that Braun made with regard to detectors came in his Nobel Lecture on December 11, 1909 on the occasion of the Nobel Prize award made jointly to himself and Marconi for their respective contributions to wireless telegraphy. The subject of his work on detectors occupied less than a paragraph in the twenty-page document memorializing his speech, and there was nothing new or notable in the lecture that was not addressed in his 1906 paper.<sup>14</sup> What is notable, however, is that the authors of Braun’s biography entitled *Ferdinand Braun* somehow concluded from this lecture that Braun had actually performed his first detector experiments in 1899—two years earlier than May 1901, the earliest date of Braun’s experiments mentioned in his 1906 article. The earlier 1899 date, if valid, would put Braun in the forefront of those who discovered radio-wave detection by crystals—clearly ahead of Jagadis Chandra Bose, who discovered one form of a galena detector circa mid-1900, as described later. It should be noted that the authors did not cite Braun’s 1906 publication, and it appears they were unaware of its existence or its contents.

The authors apparently deduced the 1899 date in some unspecified way from two sentences they quoted from a passage appearing in Braun’s Nobel lecture; only the words in bold were cited in their book:<sup>15</sup>

**“But always there remained with me a feeling of dissatisfaction, and with it, a faint memory which had obviously never died, but remained half-somnolent at the back of my mind. Instinctively I was driven back to this valve effect (with which I had repeatedly, though in vain, attempted to obtain direct current from oscillations of light) when I began to occupy myself with wireless telegraphy in 1898. The elements showed the expected detector effect, but at that time offered no advantages over the coherer. As the swing to aural reception of messages took place, I came back to these materials, and recognized their usefulness for this purpose in 1901.”**

Immediately following the words in bold, the authors made this rather startling pronouncement without citing any other sources:

**“The result was that in 1899 Braun did use the rectifier effect to build a crystal detector. But the device offered no advantage over the coherer in recording of code messages on a moving paper strip, the method then in use. Not until 1901, when audible signals came to be used, did Braun return to the crystal detector and recognize its utility for this purpose.”**

The 1899 date appears to be somehow linked to Braun’s mention of occupying himself with wireless telegraphy in 1898. However, the chronology of his early work is well documented—he occupied himself with propagation through water until the summer of 1899, and then turned to aerial telegraphy for the rest of the year



and into 1900 with a focus on transmission rather than reception. Even more to the point, Braun himself wrote a book in 1901 entitled *Drahtlose Telegraphie durch Wasser und Luft* [*Wireless Telegraphy through Water and Air*] published in 1901,<sup>16</sup> which is essentially a recounting of his activities in wireless telegraphy from the beginning in 1898 through the end of 1900, and there is absolutely no mention of his work on detectors.

The authors of *Ferdinand Braun* also claim that Braun used the “rectifier effect” to build the crystal set. This is an interesting claim, given the fact that no one knew any solid state wave detector operated on the principle of rectification at that time.<sup>17</sup> The discovery of rectification as it applies to wave detectors will be recounted later, where it will be seen that the principle of rectification as it applies to solid state radio detectors was not disclosed until late 1906.

The comment on rectification in *Ferdinand Braun* appears to be related to Braun’s reference in his Nobel lecture “*to this valve effect (with which I had repeatedly, though in vain, attempted to obtain direct current from oscillations of light)...*” The meaning of Braun’s allusion to the valve effect in his 1909 Nobel Lecture can be understood by the following excerpt from his 1906 publication in *ETZ*:<sup>18</sup>

*“One could think to suggest that photo-electric current is caused by this [the valve effect], which, as is known, is shown by selenium. However, the pursuit of this thought has not led me to a positive result. While currents occurred during the lighting of the*

*electrodes, which, however, at least for the main part, could be traced back to the heating effect.”*

Clearly, Braun’s allusion to a valve effect in his 1909 speech had nothing to do with detection of radio waves, and in any event, he concluded that the valve effect to which he referred was due to a heating effect—not rectification.

In summary, Braun is clearly not a contender for being the first to discover, experiment with, or submit a patent for detectors using crystalline substances. However, he was clearly among the first to discover contacts which displayed deviations from Ohm’s law, and he developed a practical psilomelane detector sometime in late 1905, for which he received a patent in October of 1906. This detector or a derivative thereof was used in commercial wireless service by Telefunken, but not until well after the crystal detector was introduced into commercial service in the U.S. in 1906.

## **EARLIEST RADIO WAVE DETECTORS (1877-1879)**

Heinrich R. Hertz is credited with being the first to generate and detect electromagnetic waves in the laboratory in 1887 using a spark gap generator and a micrometer spark gap as the radio wave detector. While Hertz may have been the first to recognize that he was generating and detecting radio waves, it was David Edward Hughes who in 1879 was actually the first to develop a spark-gap source which generated radio waves, and a series of detectors with which he was able to receive them at distances of up to 500 yards.<sup>19</sup> Of course, Hughes did not realize at the time he was generating and detecting electromagnetic waves whose existence

had been predicted by Hertz as early as December 1864,<sup>20</sup> but that is exactly what he did.

While Hughes did not fully understand the underlying phenomena, he did recognize that his results were both unusual and likely to be very important, and so he made plans to present them at the Royal Society in early 1880. Part of his plan was to present them to a selected group of his colleagues in advance, which, in fact, he did—first to Mr. W. H. Preece, Sir William Crookes, Sir W. Roberts-Austin, Grylls Adams,

and W. Grove in December of 1879, and next to Mr. Spottiswoode, Prof. Huxley, and Sir George G. Stokes on Feb 20, 1880. The presentations to these individuals, which took place at his home laboratory, went well at first, but in the end, Stokes dissuaded him presenting his results to the Royal Society, insisting that Hughes was transmitting and receiving signals by means of magnetic induction, an effect which was already well understood at the time—rather than the transmission of “current” through the “ether,” as Hughes asserted.

Discouraged, Hughes decided not to publish his results until he had time to further explore the phenomenon he had observed in more detail. Unfortunately, Hertz published his work in the interim, and Hughes was left to watch Hertz and others publish work that he had performed first. Hughes’ decision not to publish his results in 1880 was one of the greatest missed opportunities in the history of electricity and magnetism. Had he done so, electromagnetic frequencies might well be expressed today in terms of “hughes” rather than hertz.

Some historians have criticized Stokes for discouraging Hughes from publishing his results, while others have pointed out that it was Hughes who insisted quite incorrectly that the phenomenon he had observed was due to conduction through the ether—not electromagnetic radiation. While Hughes was incorrect about his theory of conduction, Stokes was equally incorrect when he insisted the phenomenon Hughes had observed could be explained by induction. Since Stokes was the “gate-keeper” for accepting publications at the Royal Society at that time, and quite senior to



Fig. 4. David Edward Hughes was well known for his inventions including the telegraph printer, the microphone and the inducting balance, but perhaps the most significant invention—and yet the least appreciated today—was the crystal detector he used to receive radio waves generated by his clock-work spark-gap wireless generator in 1879—although he was not aware that his spark-gap discharges were generating electromagnetic waves predicted by James Clerk Maxwell years earlier, or that the detector in his receiver was actually a rectifying crystal detector. (*Telegraphic Journal and Electrical Review*, Vol. IX, Dec. 23, 1882, p. 492)

Hughes in the pecking order of the Institution, he should be held to a higher standard and therefore must bear the primary responsibility for the clear injustice that Hughes suffered at his hands.

A summary of Hughes' work was finally published in 1899, but only as a consequence of J. J. Fahie writing a book on the history of wireless at the time.<sup>21</sup> Just before the book was published, Fahie remembered hearing from William Crookes that Hughes had performed some extremely interesting work in the late 1870's on wireless transmissions, and at the suggestion of Crookes, Fahie contacted Hughes and requested that he provide a summary of this earlier work. Hughes wrote a letter to Fahie describing his works, and at the end of the letter explained to Fahie that he had decided to do more research on the subject before publishing his results. However, in the interim, Hertz made the discovery of electromagnetic waves and published his findings. It was clear that Hughes had been grieved by his decision not to publish his works in the intervening years because at the end of this 1899 letter he wrote:

*"I then felt it was too late to bring forward my previous experiments; and through not publishing my results and means employed, I have been forced to see others remake the discoveries I had previously made as to the sensitiveness of the microphonic contact and its useful employment as a receiver for electric aerial waves."*

Hughes' letter was published in both the May 5, 1899 edition of *The Electrician* and in Appendix D of Fahie's book, the first edition of which was published in 1899.

Shortly thereafter, distinguished author Mr. John Munro visited Hughes at home, reviewed his work in some detail—including his apparatus and laboratory notebooks—and published a summary of Hughes' work in *The Electrical Review* of June 2, 1899. Munro's summary was written too late for inclusion in the first edition of Fahie's book, but excerpts from the article did appear in the Appendix D of the third edition published in 1902.<sup>22</sup>

*A Summary of Hughes' Wireless Experiments:* Munro's summary of Hughes' experiments began with an explanation of how he came to discover wireless detectors. In 1879, Hughes had been working with a telephone when he encountered problems with the balance on a telephone line. He invented an induction balance illustrated here as Fig. 5 to annul these effects,<sup>23</sup> and while using the induction balance, he was troubled by noises in the telephone which he traced it to a loose joint. He substituted one of his microphones for the loose joint and found that the telephone produced a sharp click each time the battery was switched on and off by the "clock interrupter" in his induction balance, which incidentally produced a spark at the

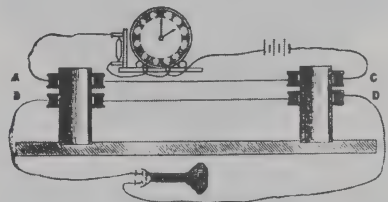


FIG. 2.

Fig. 5. The induction balance David Hughes invented to eliminate noise in a telephone circuit led him to discover that signals he generated by spark discharges could be received at substantial distances without wires.



switch. He noticed the click occurred even when there was only a single wire connected to the parallel combination of the telephone and microphone without a return wire to form a completed circuit (see Fig. 6).



Fig. 6. David Hughes, unaware of the existence of electromagnetic waves, found it strange that an open circuit consisting of a single wire connecting a spark discharge source to a telephone circuit without a return wire could induce noise into the telephone. (*The Electrical Review*, June 30, 1899, p. 884)

The occurrence a click in the absence of a completed circuit was new to Hughes, and so he decided to pursue this phenomenon—first using his existing microphones, two of which are shown in Figs. 7 and 8—and then

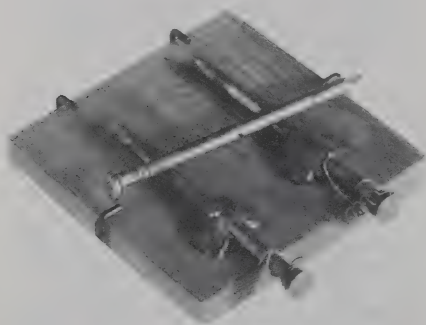


Fig. 7. By placing three nails on a wooden board, David Hughes created a transducer more efficient than Bell's telephone which was able to detect even detect a fly's footstep; Hughes was so impressed by its ability that he likened it to a "sound microscope" and decided to call it a "microphone." (Science Museum/SSPL)

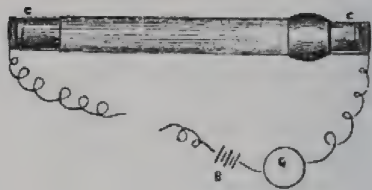


Fig. 8. Another of David Hughes' early microphones consisted a small glass tube filled with a mixture of tin and zinc particles known as "white bronze" with two carbon plugs placed in each end. (*The Engineer*, May 17, 1878).

with other configurations which he devised in an attempt to increase sensitivity. Hughes developed a number of such devices—later characterized as microphonic detectors, a few of which were described as follows in the summary published by Munro in 1899:<sup>24</sup>

"Of course it was highly important to find the most sensitive form of microphone to receive the rays, as we may call them. Contacts of metal are apt to 'cohere,' or stick together, apparently by the electrical waves welding them. A microphone which is both sensitive and self-restoring, that is to say, does not cohere, is made with a carbon contact resting lightly on bright steel. Such a receiver is shown in Fig. 9 where C is a carbon pencil touching a needle N, and S is an adjustable spring of brass by which the pressure of the contact can be regulated with the disc, D. An extremely sensitive, but easily deranged form of microphone is represented in Fig. 10, where S is a steel hook, and C is a fine copper wire with a loop on the end which has been oxidized and smoked in a flame. The carbonized loop and steel contact are inserted into a small bottle, B, for safety. Another form of micro-

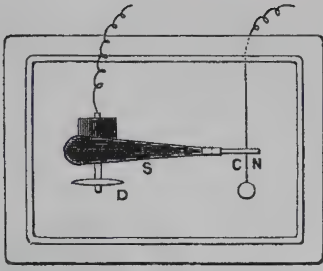


Fig. 9. The heart of David Hughes' receiver was a sensitive and self-restoring "microphone" which consisted of a carbon contact resting on bright steel with a brass spring to adjust the contact pressure; Hughes' "microphone" was actually the first known semiconductor junction used in a wireless receiver. (*The Electrical Review*, June 30, 1899)

phone which the professor tried was a tube containing metal filings, which precedes the Branly coherer of 1894, but as the cohering of the contacts is a disadvantage, he abandoned it and regards the name "coherer" as a mistake. Contacts of iron and mercury are sensitive, but very troublesome. Iron and steel cohere, but are sensitive,

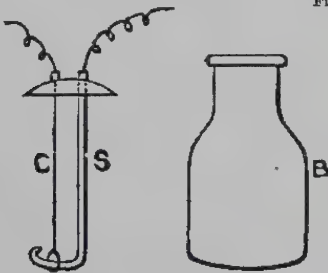


Fig. 10. David Hughes made an extremely sensitive form of a microphone detector consisting of a steel hook, S, and a fine copper wire, C, with a loop on the end which had been oxidized and smoked in a flame. (*The Electrical Review*, June 30, 1899)

and keep well when immersed in a mixture of petroleum and vaseline, which, though is an insulator, does not bar the electric waves from them."

With more sensitive detectors in hand, Hughes found he was then able to discard the single interconnecting wire, and he began to transmit signals between his "transmitter" (consisting of a battery, clockwork interrupter, and a coil), and his "receiver" (consisting of a telephone, a microphonic detector and a small battery) as indicated in Fig. 11. Many of the artifacts used by Hughes in his historic experiments are preserved at the Science Museum in London. For example, the clock-work spark transmitter and several of the detectors with a carbonized steel loop contact which Hughes inserted in a bottle is shown in the photograph of Fig. 12.

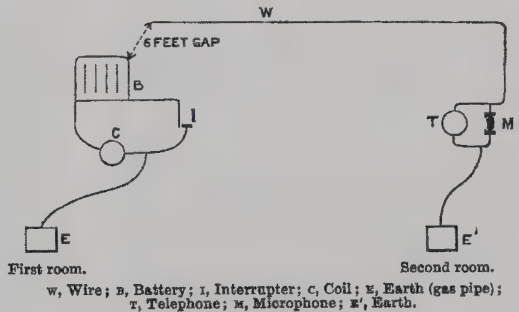


Fig. 11. David Hughes discarded the single interconnecting wire and began to communicate between his "transmitter"—consisting of a battery, clockwork interrupter, and a coil—and his "receiver" consisting of a telephone, a microphonic detector and a small battery. (*The Electrical Review*, June 30, 1899)



Fig. 12. David Hughes' microphones and wireless apparatus constructed c. 1878-79 from left to right are: an experimental microphone consisting of a carbon pencil resting in a carbon cup; a rectangular cell; a clockwork driven spark transmitter (the first radio transmitter in the world); a variable resistor; two experimental microphones consisting of needles suspended in contact with blocks of gas carbon; a microphone detector (the first radio receiver in the world); another cell; and a Bell telephone receiver. (Photo and caption courtesy of Science Museum/SSPL)

He first transmitted between rooms in his house at distances of about six feet, but beginning in October 1879, Hughes began to transmit from his home on Great Portland Street in London to points around his neighborhood at distances up to 500 yards. Munro summarized Hughes' accomplishments as follows:<sup>25</sup>

*"Prof. Hughes had now got all the principle elements of the 'wireless telegraph' as we know it, and since he was groping in the dark before the light of Hertz arose, it seems little short of magical that in a few months, I might almost say weeks, and in using the simplest means, he forestalled the great advance of nearly 20 years."*

From an historical perspective, the detectors are the most interesting part of Hughes' apparatus.

He actually discovered the major types of detectors used in the early days of wireless, including the non-restoring iron-filing and point-contact coherers, the self-restoring iron-mercury coherer, and the crystal detector. These devices are described briefly in the following paragraphs.

*Hughes' Non-restoring Coherers:* Munro described two of Hughes' devices in his 1899 publication as: "contacts of metal [which] were found to be apt to stick together, or 'cohere,' as we now say," and a second device as "a tube containing metal filings, which forestalls the Branly tube, but as the coherence of the filings was a disadvantage he abandoned it." These two non-restoring devices clearly preceded the discoveries of the coherers by Branly in 1890 described later in this article.



Hughes discarded them in favor of the so-called “self-restoring” devices described next because they remained sensitive after repeated exposure to electromagnetic radiation. Devices that remained sensitive were better suited to his repetitive-pulse transmitter driven by a clock-work motor.

It must have been distressing for Hughes to see Branly’s device—which was essentially his iron-filing microphone—became the standard detector for wireless telegraphy by 1900. However, it must be recognized that he did discard this device in favor of the self-restoring devices described next, and if his work had been published, it is quite possible that the iron filing coherer would never have been used in wireless telegraphy.

*Hughes’ Self-Restoring Steel-Carbon Detector:* The crossed steel-carbon rod device of Fig. 9 is arguably the most important wireless detector from an historical viewpoint. The carbon pencil resting on the steel rod was characterized as a self-restoring coherer by Munro in 1899, although Hughes thought the term “coherer” was ill-suited for his devices because they returned to their original sensitive state instantly and automatically without cohering. Hughes himself characterized this device in his notebooks as a “microphonic joint,” a “microphonic contact,” or a “thermo-electric joint.”

In fact, this carbon-steel device is the first solid-state semiconductor device used for detection of radio waves—specifically a point-contact semiconductor junction with a spring to adjust contact pressure. This device is a crystal detector in every sense of the word—it is formed by a point con-

tact between steel and carbon; carbon being a crystalline semiconductor material. While it may not be a naturally occurring mineral like galena, it is an elemental semiconductor just like silicon or germanium. It was later characterized as a crystal rectifier along with other crystalline detectors such as, carborundum, silicon, psilomelane, and tellurium-aluminum to name just a few. For example, Louis W. Austin of the Bureau of Standards characterized the carbon steel junction as a contact rectifier and was the first to publish I-V characteristics for this detector along with those of silicon-steel and tellurium-aluminum crystal detectors (see Fig. 13).<sup>26</sup>

The cynic might say that while Hughes invented this device in 1879, he did not publish his results until May 5, 1899—the date which should be used for purposes of determining its precedence. However, the general rule for priority of invention is the date of first public disclosure—which does not nec-

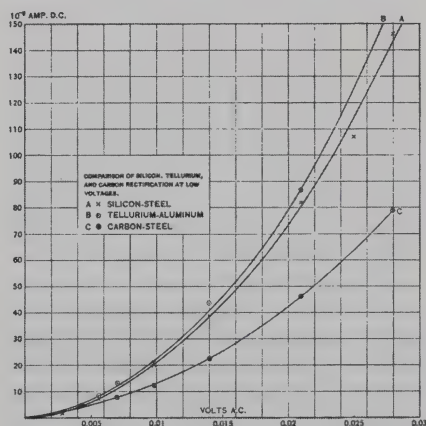


Fig. 13. Louis Austin characterized the carbon-steel junction as a contact rectifier and was the first to publish its I-V characteristics (lower curve “C”) along with those of silicon-steel and tellurium-aluminum crystal detectors. (Bulletin of the Bureau of Standards, Aug. 1908)

essarily require publication in a journal. In this case, Hughes' work was formally disclosed to a rather large group of Hughes' peers in 1878-79—a fact that is well documented and virtually indisputable. Further, this line of thinking is rendered moot by the fact that there were no other devices qualifying as a rectifying solid-state crystal detector appearing in any publication before (or even close to) the date Hughes' work was first published in *The Electrician*, on May 5, 1899. Clearly, by any standard, Hughes' steel-carbon detector precedes all other claims for a solid-state point-contact semiconductor device as a detector of radio waves.

It is interesting to note that not only was the Hughes steel-carbon detector the first crystal detector to receive radio waves in 1879, it was also the first crystal detector to be used by a wireless telegraphy company in 1901, the American Wireless Telephone and Telegraph Co. and its subsidiary, the Pacific Wireless Telegraphy Co. in 1902,<sup>27</sup> and also by other companies—most notably the Massie Wireless Telegraph Company circa 1905. The Massie detector consisting of a single steel needle resting horizontally across two beveled carbon blocks pictured later in this article was almost identical to the original Hughes detector configuration.

It is also somewhat ironic that Hughes' steel-carbon crystal detector which was the first crystal detector to be discovered and the first one to be used in wireless telegraphy was also the last to find widespread service in fox-hole crystal sets used during WW II.<sup>28</sup> The fox-hole receiver chronicled in *QST* shortly after the end of the war consisted of a steel razor blade in contact with piece of pencil lead

attached to a wire acting as a cat's whisker (see Fig. 14).

*Hughes' Self-Restoring Iron-Mercury Coherer:* While Munro mentioned Hughes' iron-mercury coherer only in passing, this device is sufficiently important from an historical point of view to merit special attention. A mercury device quite similar to this—the Italian Navy Coherer—was used by Marconi in his transatlantic experiment, and it has been suggested that Bose was the first to discover an iron-mercury coherer.<sup>29</sup> It will be seen that David Hughes was the first to discover the iron-mercury coherer in 1879 and to demonstrate that it was a self-restoring coherer.

Munro's description of Hughes' sensitive iron-mercury coherer is short, but it is no shorter—nor does it contain any less information—than the descriptions published by others who later experimented with iron-mercury coherers.<sup>30</sup> Fortunately, the very short description of this detector in Munro's 1899 publication is by no means complete. Hughes' note-

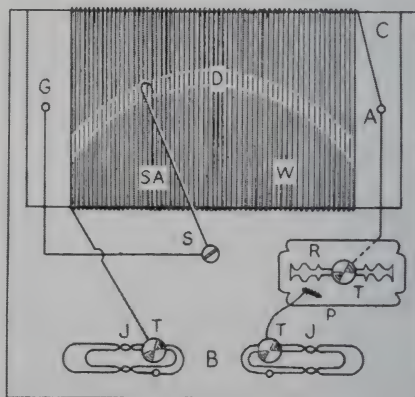


Fig. 14. This fox-hole crystal set with a wire wrapped around a pencil lead point (carbon) acting as a cat's whisker resting on a steel razor blade was used to receive radio stations WWII. (*QST*, Sept. 1945)

books contain unpublished entries which describe his iron-mercury coherer in sufficient detail to fabricate an operating model—which has been done as described below. The most telling entry appears in his notebook dated October 24, 1879, a date by which Hughes had physically separated his receivers from his clockwork-driven spark transmitter and was receiving signals through the air:<sup>31</sup>

Oct 24 [1879 notebook]: *Extra Current* [title] *Good Important* [appears in the margin] *“Found that mercury bottle with iron wires give out tones equal to best and that it was wonderfully improved by using a battery in the shunt circuit the battery makes such a difference that is probable that a battery alone would do if we manage it so it gives continuous sound of polarization—sounds which resemble Stroh’s magnet.”*

Hughes compared the continuous sounds he heard in his telephone to those made by a Stroh’s magnet—the magnet on a land-line telegraph sounder manufactured by Augustus Stroh which was designed to produce the clicks interpreted by operators as letters of Morse code. It becomes obvious why Hughes chose a Stroh’s magnet for this allusion when reading his description of some experiments he performed at Stroh’s telegraph instrument “manufactory” which were witnessed by Mr. Stroh himself:<sup>32</sup>

*“The sounds seemed to slightly increase for a distance of 60 yards, then gradually diminish, until at 500 yards I could no longer with certainty hear the transmitted signals. What struck me as remarkable was that, opposite certain houses, I could hear better, whilst at others the signals*

*could hardly be perceived. Hertz’s discovery of nodal points in reflected waves (in 1887-9) has explained to me what was then considered a mystery.*

*“At Mr. A. Stroh’s telegraph instrument manufactory, Mr. Stroh and myself could hear perfectly the currents transmitted from the third story to the basement, but I could not detect clear signals at my residence about a mile distant. The innumerable gas and water pipes intervening seemed to absorb or weaken too much the feeble transmitted extra currents from a small coil.”*

It is clear from his notes that he not only used a mercury coherer to receive signals, but that his mercury coherer was self restoring—otherwise he would not have heard the closely-spaced signals which produced the “continuous sounds” as he recorded in his notebook. Indeed, in 1909, W. H. Eccles found that a coherer made of a wire dipping into mercury in conjunction with a telephone as an indicator was self-restoring.

This author fabricated a device based on Hughes’ description and performed tests of the device to determine sensitivity and confirm self-recovery characteristics (see Fig. 15). The test setup and conditions were the same as those described in a previous paper which reported on the results of an extensive series of tests on mockups of the Italian Navy Coherer.<sup>33</sup> The reader is referred this paper for a detailed description of the test setup and test results for the Italian Navy Coherer.

The Hughes iron-mercury coherer shown here was placed in series with a telephone and a voltage source providing a bias voltage of 0.5 volts, which was then





Fig. 15. This reproduction of David Hughes' iron-mercury coherer based on his notes was used in experiments to confirm his statements indicating that it was both sensitive and self-restoring.

excited by a  $\sim 3 \mu\text{sec}$  sine-wave burst from a 50 ohm signal generator consisting of three cycles of a 800 khz sine wave (resembling the waveform thought to have been generated by the transmitter in Marconi's transatlantic experiment). This pulse was repeated once per second, and each successive pulse was clearly heard in the telephone without the need for taking any action to restore sensitivity. The mockup of Hughes' mercury coherer was both self-restoring and about as sensitive as mockups of the Italian Navy Coherer tested previously.

Once again, it is clear that Hughes was the first to discover a self-restoring iron-mercury-iron coherer which is very similar in construction to the Italian Navy coherer developed more than 20 years later. Both devices used mercury as the critical agent for self-restoration and had small contact areas between the electrode and the mercury—except

that the Italian Navy coherer used a small drop of mercury between two larger cylindrical electrodes, while the Hughes coherer used a large blob of mercury in contact with two very small cylindrical electrodes.

### EARLY NON-RESTORING COHERERS (1889-1899)

Immediately following the discovery of radio waves by Hertz, the search was on for more sensitive detectors. Édouard Branly and Sir Oliver Lodge are credited with being the first to develop and demonstrate devices sufficiently sensitive and reliable to detect electromagnetic waves at significant distances. Both Branly's and Lodge's devices were remarkably similar to two of the microphonic joints Hughes discovered in 1879, although there is no evidence of a connection between Hughes' early work and their later discoveries.



Fig. 16. Édouard Branly discovered cohesion of iron filings in a tube when exposed to spark discharges in 1890, which lead to the development of the iron-filing coherers used in wireless telegraphy.

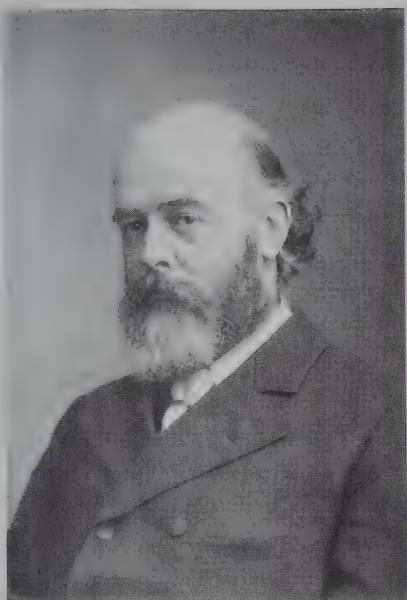


Fig. 17. Sir Oliver Lodge is generally credited with improving and popularizing Branly's radio-conductor and naming it a coherer.

Branly is credited with discovering two distinctly different devices in 1890 that he would later call radio-conductors.<sup>34</sup> One type of radio-conductor was a cylinder filled with iron filings whose resistance dramatically decreased when exposed to electromagnetic radiation from the discharge of a nearby Leyden jar (see Fig. 18), and the other was a point-contact device consisting of lightly-oxidized crossed copper or iron rods that which also responded to electromagnetic waves in a similar fashion (see Fig. 19). Lodge claimed to have discovered a point-contact device with a "double-knob" configuration displaying cohesion before Branly in 1889, but this author finds Lodge's claim to be suspect, as explained later in this section.

Neither Branly nor Lodge recognized the potential of their re-

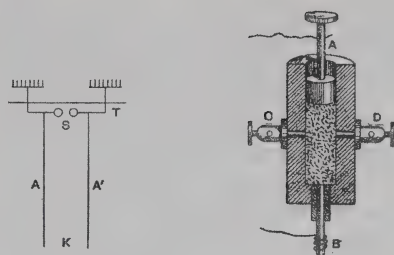


Fig. 18. Édouard Branly discovered that the resistance of iron filings contained in a tube (right) dramatically decreased when exposed to nearby discharges produced by a Leyden jar (left). (*The Electrician*, June 26, 1891)

spective devices as detectors of Hertzian waves at the time of their discoveries. It was several years after the publication of Branly's discovery before Lodge recognized the potential of Branly's iron-filing radio-conductor for this purpose. After experimenting with it, Lodge made several significant improvements to it and then gave several demonstration lectures using his improved device which popularized both the device and the "coherer" name he used to describe the device in his lectures. Marconi further perfected the iron-filing coherer and received a patent for it in the context of an entire wireless system on July 2,

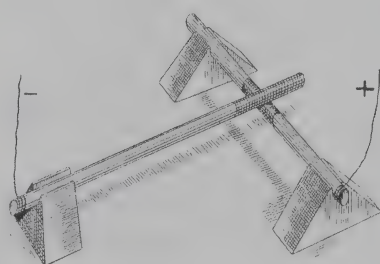


Fig. 19. Édouard Branly also discovered that the resistance of crossed oxidized rods consisting of iron or copper dramatically decreased when exposed to nearby discharges of a Leyden jar. (*The Electrician*, June 26, 1891)

1897. While the point-contact coherer was more sensitive than the iron-filing coherer, it was sufficiently difficult to decohere after each pulse that it was never used in wireless telegraphy.

Meanwhile, Jagadis Chandra Bose had invented an iron spiral coherer in 1895 which he used in a notable demonstration to fire a pistol and ring a bell at distances of up to 75 feet. Lodge later described Bose's coherer as a "half-way house" between the point-contact coherer and the iron-filing coherer. It is important from an historical point of view, but, in fact, it was never contemplated for wireless telegraph applications. All three types of coherers are described in turn in the following paragraphs—the iron-filing coherer, the point contact coherer and Bose's iron spiral coherer.

*Evolution if the Iron-Filing Coherer:* Observations of the change in conductivity in tubes of iron filings were reported as early as 1835 by P. S. Munck of

Rosenschöld,<sup>35</sup> later by Varley in 1870,<sup>36</sup> and again by Temistocle Calzecchi-Onesti in an 1886 publication.<sup>37</sup> However, their works had no influence on the discovery or development of the iron-filing coherer for several reasons. First, Hertz had not yet discovered radio waves, so no thought could have been given to using this phenomenon for detection of radio waves at the time of their discoveries. Second, in all three cases, the change in conductivity was caused by a discharge of current directly into the device, rather than by exposure to electromagnetic radiation, thus the experimental configuration would not suggest an application to radio-wave detection.

David Hughes was actually the first to discover an iron-filing tube (his iron-filing microphone) was sensitive to a nearby electric spark discharge in 1879—preceding Branly's discovery by at least ten years—although Hughes did not realize that he was generating radio waves at the time. Further, his observations were not published until 1899, well after the discoveries by Branly, and the improvements to the coherer made by Lodge, Marconi and others.

By all accounts, Branly was the one who first discovered and published results in late 1890 that lead directly to the development of the coherer. Branly's work is distinguished from previous work (except for Hughes) in that he noted changes in conductivity of both the iron-filings tube and the point-contact device consisting of crossed copper rods when exposed to the electromagnetic fields produced by near-by sparks—as opposed to direct discharges of currents into these devices. He was also the first to provide significant quantitative data on the effects he



Fig. 20. Jagadis Chandra Bose was an exceptional scientist who made major contributions to the development and understanding of the coherer during the period 1896 to 1901.



observed. Among the many results Branly found, the following are perhaps the most significant:

1. The resistance of a tube of iron filings and other common metals decreased from millions of ohms to hundreds of ohms when exposed to a nearby electrical discharge—with or without wires attached to the tube,
2. The drop in resistance occurred in all directions, and occurred whether or not a battery bias was applied,
3. A mechanical shock restored the resistance,
4. An *increase* in resistance was also observed with columns of certain materials such as antimony or aluminum powder subject to pressure, peroxide of lead and platinized glass, and
5. Crossed oxidized copper rods also exhibited a decrease in resistance from 80,000 ohms to 7 ohms after exposure to the influence of the electric spark; similar results were obtained with oxidized steel rods.

Branly's work was published only a few years after Hertz published his discovery of electromagnetic waves, and while the search was on for more sensitive detectors than that used by Hertz, there is no evidence that Branly connected his research with the detection of electromagnetic waves. Branly's work went unnoticed for several years in England where Oliver Lodge and some of his colleagues were searching for more sensitive detectors. Lodge is often credited as the one who finally recognized that Branly's iron-filing coherer would make an excellent radio wave detector but the facts as related in the next few paragraphs do not support this contention.

Branly's paper went unnoticed in England until 1893 when it was brought to the attention of the London Physical Society by Mr. W. B. Croft on Oct. 27, 1893.<sup>38</sup> Prof. George M. Minchin was in attendance and noted that the phenomenon Branly had observed was analogous to what he had observed from the effects of spark discharges on his impulsion cells (a type of selenium photoelectric cell) at distances of up to 130 feet. He subsequently wrote a paper for presentation to the Physical Society describing the similarities, and concluded both effects were caused by electromagnetic radiation produced by discharges from Leyden jars.<sup>39</sup> Lodge candidly admitted in his "History of the Coherer" published in *The Electrician* in 1897 that he did not see Branly's paper published in late 1890,<sup>40</sup> and first heard of Branly's work when he read about it in an advance copy of Minchin's paper he obtained just before it was presented on Nov. 24, 1893.

It is clear that Minchin's paper prompted Lodge to investigate the possibility of using Branly's device as a detector of electromagnetic waves. Lodge went on to relate in his "History" that upon reading Minchin's paper he "*at once proceeded to try the Branly tube of filings, and found it to far superior in manageability to either the Boltzmann gap [an alternative non-cohering method of detecting Hertzian waves with which he had previously experimented] or his own delicately adjusted knobs;*<sup>41</sup> *though immediately afterwards, he and FitzGerald together arranged a single point coherer of iron and aluminum (point of sewing needle resting on aluminum foil), of what was at the time extraordi-*

nary sensitiveness and reasonable manageability.” Lodge’s single point coherer made from iron and aluminum referred to here is shown in Fig. 21. Clearly, Lodge had understood the significance of Branly’s devices (both the iron filings coherer and the point contact coherer consisting of cross rods) and their ability to act as sensitive indicators of electromagnetic radiation.

Between January and June of 1894, Lodge and his colleagues undertook a program of testing and improving the Branly’s iron-filing tube so it could be used in a number of quasi-optical experiments that were being created at the time to demonstrate the reflection, absorption and transmission properties of Hertzian waves. According to Lodge, improved methods of arranging the filings were gradually adopted, especially by sealing them in a vacuum or partial vacuum with a hydrogen background. Tapping back was first accomplished by hand, but automatic tappers were soon ar-

ranged—first with an electric bell mounted on the base of a filings tube to impart vibrations to the tube, and later with a clockwork tapper consisting of a rotating spoke wheel driven by the clockwork of a Morse instrument which gave the tube a series of jerks to restore sensitivity at regular intervals.

On June 1, 1894 Lodge gave a lecture at the Royal Institution to honor Hertz entitled “The Works of Hertz”. The objective of the lecture was to describe the nature of Hertzian waves, and the quasi-optical experiments Lodge had been preparing were intended to illustrate the various principles involved. Lodge’s improved iron-filing coherer shown in Fig. 22 was used to demonstrate the transmission and reception of electric waves from one room to another, but reception of signals for wireless telegraphy applications was not specifically addressed in this lecture. Lodge made a similar presentation to the British Association at Oxford in August 1894, but this time, according to colleague Silvanus Thompson, Lodge showed that the Branly tube could be used to receive telegraphic signals through walls and at large distances, which at that time for Lodge was up to 100-150 yards.<sup>42</sup> These two lectures—coupled with his book *Works of Hertz* published shortly thereafter—stimulated the public’s imagination with telegraphy and popularized the coherer.

With regard to the coherer name, it is generally believed that Lodge gave the coherer name to Branly’s iron-filing coherer, but in truth, he reserved that name for the single point-contact coherer consisting of two metal electrodes in close proximity, and never intended for it to be applied to other configurations—particularly the



Fig. 21. Oliver Lodge characterized his point-contact coherer consisting of a spiral of a thin iron wire mounted on an adjustable spindle pressing against an aluminum plate as “*astonishingly sensitive.*” (Science Museum/SSPL)

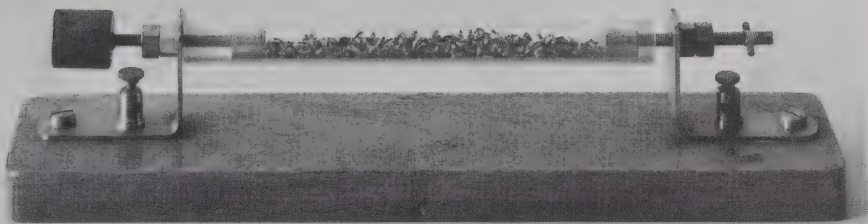


Fig. 22. Oliver Lodge made improvements to Branly's coherer and used it in several lectures during 1894 to describe the nature of Hertzian waves and demonstrate detection of radio waves. (Science Museum/SSPL)

iron-filing tube of Branly. This is evident from his writings. For example, in 1907, he wrote that "*coherer*" was "*the name I gave to the minute gap between a pair of metals in ostensible but incomplete contact.*"<sup>43</sup> He went on to say: "*Since that time [1894] all these modes of detection, whether in the form of a single specially arranged contact-grip, or the form of a multiplicity of loose contacts, have been called 'coherers' indiscriminately.*" The sentiment of his statements is reinforced by a wall diagram he used in his 1894 lecture and reproduced in his 1894 book which listed "Coherer (Hughes and Lodge)" as a separate entry from "Filings (Branly)," both of which appear under the category of "Microphonic Detector."<sup>44</sup> Clearly, the press did not make that distinction in its reporting to the public.

While Lodge was improving the Branly coherer in England, Marconi turned his attention to a program of improvements in Branly's coherer during the period 1894-95 in Italy. His aspirations were much more grandiose than Lodge's in that he was determined

to develop a practical coherer that could be used in commercial work for long-range telegraphy as opposed to demonstrations in the laboratory. Marconi focused on optimizing size of the filings and materials, the size and diameter of the tube, the shape of the electrodes, and the packaging, for which he selected an evacuated glass tube to prevent oxidation. He used a sensitive relay with a battery to send current through a tape-instrument or a sounder and the decohering tapper. The tapper worked on the same principle as a bell, but the hammer was arranged to tap the tube itself and with just the right force. Marconi's first receiver is shown in Fig. 23.<sup>45</sup>

Marconi brought his receiver with this coherer to England in 1886, hidden from public view in box. He applied for provisional protection entitled "Improvement in Transmitting Electrical Impulses and Signals and in Apparatus Therefore." Shortly thereafter, he had the good fortune to obtain support from Sir W. H. Preece who was the Chief engineer of the Post Office, the organization responsible for telegraphy in



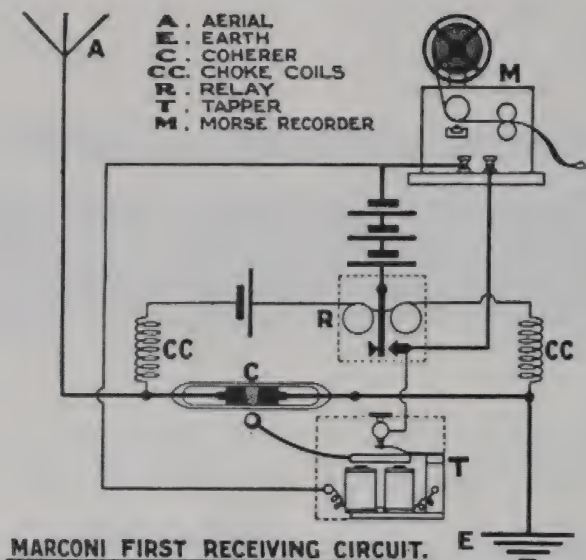


Fig. 23. Guglielmo Marconi's first receiver consisted of a coherer, battery, choke coils, relay, automatic tapper, and a Morse recorder. (R. Stanley, *Wireless Telegraphy*, 1919)

England. He was awarded his patent in 1897, and backed by capital and influence, Marconi gradually signaled over greater and greater distances, and eventually becoming the leading force in wireless telegraphy in both England and the U.S. Throughout this period, he continued to make improvements in his coherers. For example, he later beveled the edges of the electrodes to a "V" shape so the active electrode area could be varied by rotating the tube—thereby changing the sensitivity of the coherer. One of the earlier versions of Marconi's iron-filing coherer is shown in shown in Fig. 24.

There were other individuals and companies who contributed to the development of the iron filing coherer, but it is beyond the scope of this article to go into more detail. Suffice it to say that the coherer soon became the standard detector for virtually all wireless

systems, and Marconi's coherer was about the best that could have been achieved. There were two major limitations fundamental to the coherer—lack of speed and sensitivity. Because the filing coherer was non-restoring, it needed a tapper-back which ultimately limited its speed of word reception. Popoff did file a patent (U.S. 722,139) with an application a date of March 8, 1900 for claims on a device he described as a "*self-decohering coherer system*." This device was an iron-filing type of coherer but it used grains obtained by crushing tempered steel balls in lieu of the usual iron filings. His coherer, which was manufactured by Ducretet and used by the Russian Navy,<sup>46</sup> may have been able to ameliorate the problem of limited word-rate, but not lack of sensitivity, which ultimately caused the demise of the coherer.

The coherer was actually a very sensitive device for short pulses

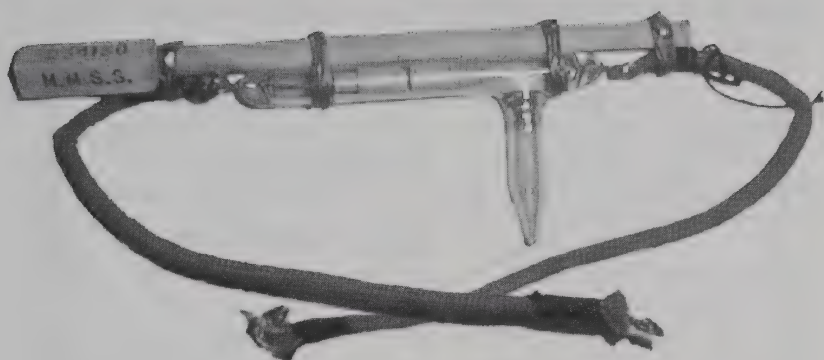


Fig. 24. Guglielmo Marconi's coherer was an improvement on Lodge's modification of Branly's radio-conductor. (Courtesy John Jenkins, [www.sparkmuseum.com](http://www.sparkmuseum.com))

produced by spark-discharge devices used for development of early detectors as well as in early transmitters. In fact, a good iron-filing coherer was more sensitive than the most sensitive crystal detector for short pulses produced by spark discharges. This author has measured the detection threshold for a several coherers including a reproduction of Marconi's coherer pictured in this publication using a spark discharge source and compared it with the thresholds of a number of crystal detectors including a modern 1N34A germanium detector. The coherer was consistently more sensitive than the crystal detectors by a factor of four or more. However, when the thresholds were compared for sources with pulse widths of approximately 10-20  $\mu\text{sec}$  or greater (characteristic of transmitters appearing in the early 1900's), the sensitivity of the crystal detector exceeded that of the coherer.

The reason for this is rather obvious. The coherer is fundamentally dependent on peak voltage (and perhaps rate of rise, as well), and therefore its sensitivity is independent of pulse width. Independent of how much energy is

in the pulse, when the coherer switches, the battery in the circuit provides more than sufficient energy or power to activate the sensor (e.g., a bell or earphones). On the other hand, for short pulses, the rectifying crystal detector must convert enough energy from the a-c radio signal to low frequencies in order to produce an audible signal in the telephone (high-frequency a-c signals do not produce audible tones in a headphone). The amount of energy in the low frequency signal produced by the detector is dependent on both amplitude *and* pulse width. Thus, for the same signal amplitude, longer pulses produce more energy in the detector output. Therefore the threshold of audibility in a headphone connected to a crystal detector decrease as the pulse width increases.

The detection threshold for a modern 1N34A detector with headphones as a function of pulse width is shown in Fig. 25, where it can be seen that the sensitivity increases (i.e., the detection threshold decreases) proportional to the square root of pulse width for increasing pulse widths up to 100-200  $\mu\text{sec}$ , at which point it becomes independent of pulse

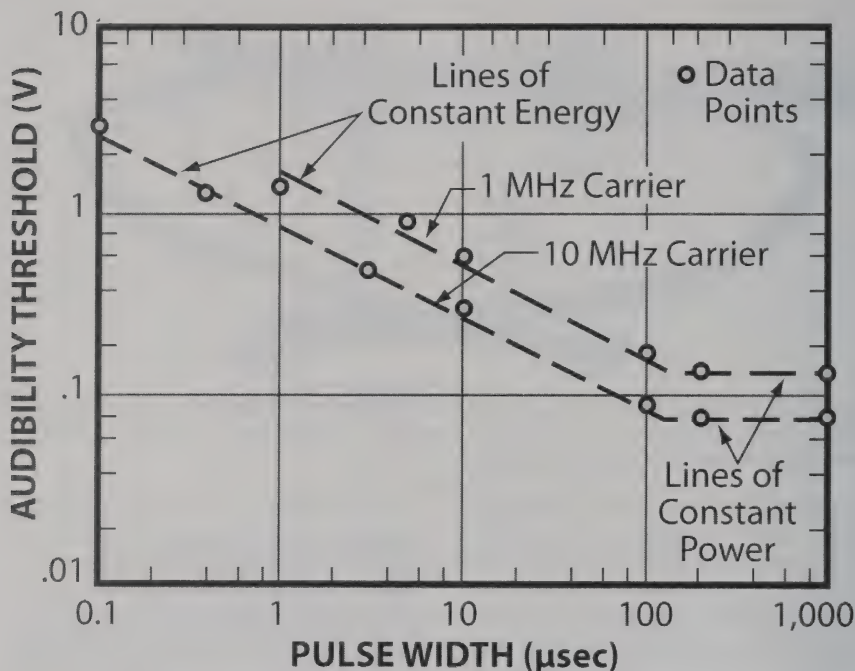


Fig. 25. The minimum modulated rf signal amplitude required to produce an audible signal in a Brandes "Superior" headset with a 1N34A diode as a detector is inversely proportional to the square root of the pulse width for pulse widths less than  $\sim 200 \mu\text{s}$ . (E. Wenaas, *AWA Review*, 2008)

width. The underlying phenomenology is more fully discussed in the article from which this figure was taken.<sup>47</sup>

As the pulse width of the wireless transmitters increased, the sensitivity of the rectifying crystal detector also increased (proportional to the square root of pulse width). In essence, the crystal detector was able to take advantage of the additional energy in the longer pulses, while the coherer—which was not sensitive to energy in the pulse—could not take advantage of the extra energy. As a result, the rectifying detectors became relatively more sensitive than the iron-filing coherer in the early 1900's as transmitter pulse widths increased, and that is when rectifying devices began to replace the coherer.

*Evolution of the Point-Contact Coherer:* Non-restoring point-contact coherers generally consisted of contacts between common metals with lightly oxidized surfaces in various combinations such as iron-iron, copper-iron, iron-aluminum and other combinations of common elements. The contact points were formed by lightly contacting spheres or cylinders, or pointed wires in contact with plane surfaces. The point-contact coherers were distinctly different from the iron-filing coherers in two ways. First, because they were not self-restoring, they needed adjustment after receiving each pulse of electromagnetic radiation, and they were not as easy to readjust as the iron filing coherers, which were easily restored to sensitivity with a single tap. Second, they were never used in wire-



less telegraphy because the thin oxidation layers could not withstand much pressure, and as a result, they were extremely sensitive to shock and vibration.

In Lodge's 1897 "History of the Coherer," he clearly stated that he had discovered the point-contact coherer in 1889, predating Branly's discovery by at least a year. His view on the discovery of the point-contact device is myopic at best, and is for the most part inconsistent with the known facts. It would appear that Lodge distorted this history to support an unfounded claim that he first discovered the point-contact coherer.

Lodge began his version of the evolution of the coherer in his "History" with preliminaries on observations of the cohesion principle as it relates to dust particles, water jets, and finally an application to clearing of smoke in a box in 1883—none of which seem particularly relevant to the subject at hand. Lodge then made the statement that "*the next observation of cohesion under electrical influence was made by the writer [i.e., Lodge] in 1889, while working at the protection of telegraphic instruments and cables from lightning...*" He goes on to say that his "*observation of cohesion was a bye-issue, noticed when the knobs were brought too close together.*" He concludes by saying that "*the adhesion of the two surfaces was demonstrated by an electric bell and a single cell [battery] in the circuit,*" and that "*every time the spark occurred, the bell rang, and continued ringing until the table or some part of the support of the knobs was tapped so as to shake or jar them asunder again.*"

Note that Lodge's claim for observing cohesion in a point-contact device in 1889 precedes the

discovery of cohesion by Branly published in 1890, and makes no mention of Hughes' discoveries of point-contact coherers in 1879, with which he was clearly familiar. It is also interesting to note that nowhere in his "History" does he ever mention the point-contact devices that Branly described in his 1890 paper.

Worse yet, Lodge's description of how he discovered the point-contact coherer in his 1897 "History" is totally at odds the account he wrote immediately upon learning of Branly's work by reading a copy of a paper by Minchin just before it was presented to the Physical Society on Nov. 24, 1893. Minchin's paper contained a description of Branly's work on cohesion resulting from discharges of Leyden jars, and Lodge was most anxious to document the fact that he had observed cohesion from discharges of Leyden jars years before. He was so anxious, in fact, that he did so by writing a note to the Physical Society dated Nov. 23, 1893—the day before Minchin's paper was to be read—describing his earlier work and asking that it be read immediately following Minchin's paper. Lodge's note was, in fact, read after Minchin's paper, and it was also published in the *Proceedings of the Royal Society*, placed immediately following Minchin's paper.<sup>48</sup> Lodge's note began as follows:

*"The recent experiments of Mr. Croft and Prof. Minchin remind me of an observation I frequently made when engaged with syntonetic arrangement of Leyden-jar circuits, or sympathetic electric resonance. I found, if the knobs of the receiver were very close together, a weak battery and bell being in the circuit that the occur-*

*rence of a scintilla at the receiver frequently caused the bell to ring for some time, and in general to show signs that the knobs were in a state of feebly adhesive contact."*

Note that this version of Lodge's discovery of coherence is clearly at odds with the later version he claimed in his 1897 "History" in which he said he first observed cohesion in the course of lightning guard experiments. There is no mention of lightning guard experiments anywhere in this note—only experiments with the syntonic circuits associated with tuned-circuit coupling. Within eight months of his note, Lodge abandoned the "syntonic experiment" version of his discovery of cohesion, and published the lightning-guard account of his discovery in his book *The Work of Hertz*,<sup>49</sup> the same version that appeared later in his "History." He never mentioned the Nov. 3, 1893 syntonic version again, and he never explained the discrepancy in the two versions.

From that point forward, Lodge consistently repeated the version of the discovery involving lightning guard experiments—exactly as it appeared in his "History" in 1897. Why he changed his story so completely and abruptly is not known. Perhaps during the course of his experiments with Branly's cohering devices immediately following Minchin's presentation, Lodge found that cohesion could not be obtained in the context of his published syntonic experimental configurations.<sup>50</sup>

A close examination of Lodge's account of his lightning guard experiments published in early 1890 reveals that it is inconsistent with Lodge's later version of how he discovered cohesion in the

course of those lightning experiments. In "History," Lodge claimed to have observed permanent cohesion in the course of lightning experiments: "*every time the spark occurred, the bell rang, and continued ringing until the table or some part of the support of the knobs was tapped so as to shake or jar them asunder again.*" This description is totally at odds with the lightning experiments he cited; there is absolutely no mention of *permanent* cohesion or any tapping of the joint to restore sensitivity in that article. Quite to the contrary, Lodge emphasized *temporary* cohesion, which of course is not characteristic of a non-restoring coherer.

Lodge specifically cites the source of his first observation of cohesion as three pages from his treatise "On Lightning Guards" where he specifically states that the plates are only "*momentarily short-circuited, as proved by replacing the galvanometer by a Léclanché [battery] and electric bell.*"<sup>51</sup> He goes on by referring to "*the infinitesimal spark which temporarily connects the plates...*" The temporary nature of the cohesion is reemphasized in the footnote: "*the short-circuiting is quite temporary.*" It should be noted he said nothing about tapping the plates or knobs to separate them.

A point not to be missed here is that in Lodge's lightning paper, he called attention to this phenomenon specifically because of the *temporary* nature of the cohesion he observed. Had the cohesion been permanent, there would have been no reason to note that fact. In the course of performing lightning experiments, he was using a Leyden jar with a capacity of .0016  $\mu$ F charged to

approximately 10,000 volts (amounting to about 0.1 joules) to discharge a sufficient amount of energy directly into two closely-spaced electrodes to produce permanent arc welds. Consequently, an observation of permanent cohesion would not have been noteworthy. Further, if the cohesion had been permanent, he could have used the galvanometer already in the circuit with a battery to measure the resistance of the permanent cohesion—rather than having to resort to the bell and battery he used to demonstrate temporary cohesion.

It is truly surprising that Lodge would attempt to deduce something about coherer action in an imperfect joint (which occurs at a few volts or less) from lightning experiments in which a Leyden jar charged to 10,000 volts is directly discharged into the joint. It is difficult to imagine two phenomena that occur at greater differences on the energy scale than radio detectors and lighting. Estimates of the energy at which coherers operated are the order of  $10^{-9}$  joules or less, while the energy delivered to a strike point by lightning is on the order of  $10^6$  joules. Lodge used a Leyden jar source for his lightning experiments with a stored energy on the order of 0.1 joules, significantly less than that delivered by lightning stroke, but still eight or more orders of magnitude greater than that appearing across a coherer in a wireless detector.

One would think that Lodge's contemporaries would have immediately taken him to task for the making such an extrapolation. In fact, Guthe and Trowbridge did, albeit a number of years later. In 1900, they pointed out the obvious, namely that Lodge had used such large discharges in his experi-

ments that it produced visible discharges in the iron-filing tube.<sup>52</sup> They further pointed out that *"when sparks of considerable intensity were apparent, the resistance was sometimes lowered, sometimes increased, sometimes the changes were not permanent; often sparks could be seen without any change in resistance taking place."* They went on to observe:

*"From this it would appear that the phenomenon of coherer action can be best studied only when sparking is avoided. This point was thoroughly established by the quantitative experiments made by one of us a year ago in which a remarkable regularity in the behavior of the coherer was observed, undoubtedly due to the fact that the above condition [i.e., visible sparks] was avoided."*

Based on the discrepancies in Lodge's two versions of how he discovered the point-contact coherer, and the discrepancies the two versions of the results of lightning guard experiments—permanent versus temporary cohesion—it is highly doubtful that Lodge discovered either the cohering principle or the point-contact coherer. Those honors go to Hughes and Branly—Hughes because he discovered cohering devices first in 1878—even though he immediately rejected them and did not publish any of his findings until 1899—and Branly because the development of coherer followed directly from the disclosure of his experiments in 1890.

It is even difficult to credit Lodge with recognizing that the coherer would make a good detector of electromagnetic waves. A careful reading of both Croft's and Minchin's paper in 1893 re-



veals that Minchin disclosed the concept that Branly's coherer responded to the electromagnetic radiation emanating from the spark discharge he used—well before Lodge claimed to have heard of Branly's results. It is certainly suspicious that Lodge began his serious exploration of the coherer principle as a detector immediately upon reading Minchin's paper. If Lodge had discovered the principle of cohesion in 1889 as he claimed, and if had recognized that such a device would be a useful detector of radio waves before reading Minchin's paper, then why did he wait until after reading the paper to act?

*The Point-Contact Coherer as a Repetitive-Pulse Detector:* Non-restoring coherers were generally incapable of receiving repetitive pulses without restoring sensitivity between each pulse by a tap or a readjustment of the contacts. However, Lodge reported a unique method for using a non-restoring point-contact coherer to do just that—a method which has apparently escaped the attention of historians. Lodge documented the configuration for doing this in the third edition of "*Signalling Through Space*," reproduced here as Fig. 26. This figure shows a non-restoring coherer consisting of a needle (presumably steel) resting against a watch spring (also presumably of steel) in a simple series circuit with a battery and headphones.

The first received pulse puts the non-restoring coherer in a low-impedance mode which is generally considered a non-sensitive mode. However, each subsequent pulse produces a small change in coherer resistance—not the full change associated with the first pulse, but very small changes, which *if permanent* can easily be

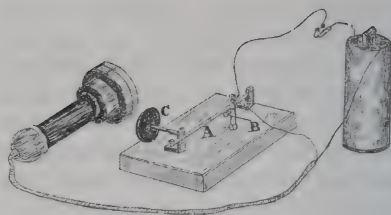


Fig. 26. A very simple but sensitive receiving arrangement used by Oliver Lodge as early as 1897 consisted of a non-restoring single-point coherer without a tapper back, a telephone and a battery. (O. Lodge, *Signalling Through Space without Wires*, May 1900)

detected by the telephone shown in the circuit of this figure. The small changes in current by subsequent pulses were measured by Lodge and his assistance in 1897 as indicated in Fig. 27 and were found to be both permanent and easily detectable. In fact, this method is more sensitive than the normal coherer mode. It generally takes 50-100 mV or even more to trigger a non-restoring

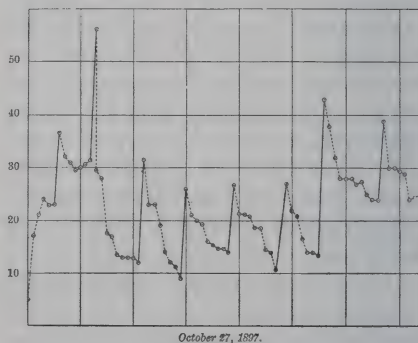


Fig. 27. The current through Oliver Lodge's receiver arrangement was sensitive to successive electrical stimuli without any mechanical tapping back. (Oliver Lodge, *Signalling Through Space without Wires*, May 1900)

coherer into the permanent conducting mode, but the threshold for detection of a step function in voltage by a telephone is only about 10 mV, so if the received electromagnetic wave produces a permanent change in resistance of the coherer that results in a 10 mV change across the coherer, it can be detected by the earphones. Depending on the battery and the telephone impedance, a change of only a few ohms to perhaps ten ohms is required to produce 10 mV.

Lodge called attention to this mode of operation in a newspaper article in *The Times* of London shortly after Marconi's announced that he used a telephone in conjunction with a self-restoring coherer in his famous transatlantic experiment in 1901.<sup>53</sup> Lodge suggested that Marconi had used this method of reception, but his suggestion was rejected by Flood Page managing Director of Marconi, who responding by saying the device (which turned out to be the Italian Navy Coherer) was completely different than anything Lodge had seen. While this was true, Lodge was referring to the *method* of communication—not the *device* used as the coherer.

Indeed, this author has made extensive measurements on mockups of the Italian Navy Coherer and found this mode of operation—designated by the author “multiple-pulse” reception for want of a better term—to exist during the course of experiments on this device. This mode was found to be stable and far more sensitive than the rectification mode for the very short, widely-spaced pulses Marconi used in his transatlantic experiment (see Fig. 28). It is distinctly different than the normal non-cohering mode—it is something of a cross between

a non-restoring and self-restoring coherer. Actually it is non-restoring in the sense that the small change in resistance produced by each pulse is permanent, but at the same time it is continuously sensitive.

*Bose's Spiral Spring Coherer.* Bose developed a unique spiral spring coherer in early 1895 for the stated purpose of exploring the optical properties of crystals. According to Bose, he was motivated to develop this device after listening to one of Lodge's coherer demonstrations in 1894. This coherer is significant, not only because it was different than the point-contact and iron-filing coherers in vogue at that time, but also because it is believed that he used this device in 1895 for a well-publicized public demonstration in Calcutta in which he showed that electromagnetic radiation could pass through solid walls and still ring a bell and fire a pistol at a distance of 75 feet from his transmitter. He also stated that he had measured electric waves in a straight line without intervening matter at a distance of one mile.

References to this demonstration popped up from time to time during the early years of the development of wireless—for example in William Preece's speech to the public in London 1896 while

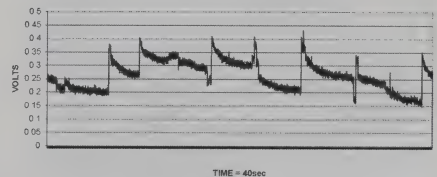


Fig. 28. The repetitive-switching mode of an iron-mercury coherer is characterized by small abrupt changes in the operating point of the mercury coherer following each pulse, as indicated by the discontinuity in voltage across the headphones in this 40 second sweep. (E. Wenaas, *AWA Review*, 2008)

introducing Marconi, and in an interview with Dam published in *McClure's* magazine in 1897. This demonstration was—and still is—occasionally cited to make claims that Bose was actually ahead of Marconi in wireless telegraphy at the time. Using range at one instant in time as the only criterion for success is somewhat myopic because while Bose built a system suitable for laboratory experiments useful for single widely-spaced pulses at limited ranges, Marconi was building an entire system—including a transmitter, receiver, and antennas—suited to long range telegraphy which would also provide for recording of telegraphic signals and maximize speed using an auto-tapping device to restore sensitivity.

Bose's coherer consisted of parallel rows of iron springs whose contact pressure could be adjusted with a thumb screw at the top (see Fig. 29). After each pulse, the receiver could be returned to sensitivity by readjusting the pressure on the springs with the thumb screw. In his "History," Lodge described this coherer as "*a half-way house between a point coherer and a filings tube*," a configuration he said he did not find "*specially convenient*." Restoring the sensitivity by adjusting a thumb screw would not have been practical in a telegraphic system, but it almost certainly could have been modified or adapted to some type of automatic tapping system for that purpose.

### SELF-RESTORING COHERERS (1897-1905)

There were two basic classes of self-restoring coherers—those that automatically returned to sensitivity after a exposure to radiation without the any external aid in the form of a mechanical tap, electri-

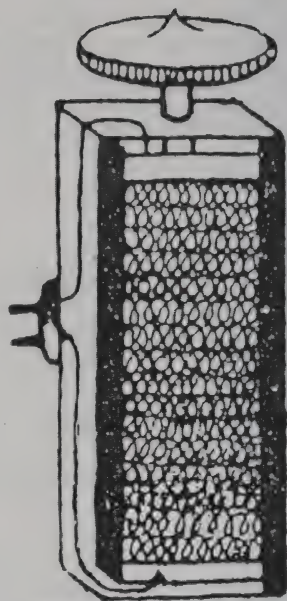


Fig. 29. Jagadis Bose's spiral spring coherer consisted of an ebonite insulator with a shallow cutout to fit a single layer of spiral steel springs with dimensions of 2 mm. in diameter and 1 cm. in length laid side-by-side, with a thumb screw at the top to adjust pressure and reset the coherer after coherence. (J. Bose, *Collected Physical Papers*, p. 6, 1927)

cal pulse, rotating wheel, etc., and those which required the aid of some external restoration system. Perhaps the most notable form of an external restoration system was the iron-mercury coherer of Lodge and Muirhead which used a small steel disk revolving over a vessel containing mercury, on top of which is placed a film of mineral oil (see Fig. 30).<sup>54</sup> The film of oil prevented the disk from contacting the mercury, but each time a signal from the antenna was applied, the insulating film was momentarily ruptured and the disk connected to the mercury—thereby allowing the signal to be recorded. Only the truly self-



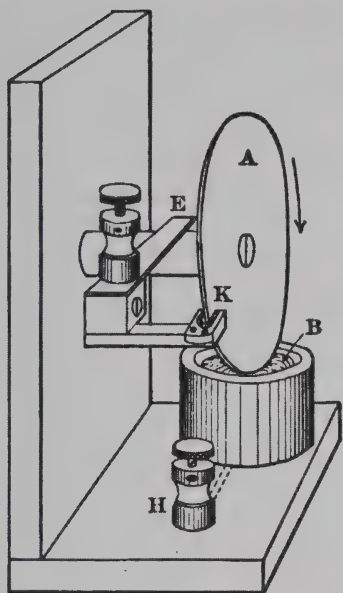


Fig. 30. The Lodge-Muirhead coherer consisted of a small steel disk rotated by a clock-work motor through a pool of mercury upon which rested a thin oil film serving to isolate the iron disk until an electrical pulse was applied, at which time the insulating film was temporarily ruptured, thus allowing current from an auxiliary battery to flow. (G. Pierce, *Wireless Telegraphy*, 1910)

restoring coherers that required no such external means of restoration are addressed in this paper.

David Hughes was clearly the first to discover devices in 1879 which were both sensitive to electromagnetic radiation and remained sensitive after each consecutive exposure. When the description of Hughes' detectors was published in 1899 by Munro, he described these devices as self-restoring coherers—a term in vogue at the time as a result of the discovery of similar devices by others beginning circa 1897. The name "auto-coherer" was also applied to this device even though it is a misnomer which implies

that these devices would automatically cohere rather than decohere. Marconi popularized the self-restoring coherer by reporting the use of three such devices in his famous 1901 transatlantic communication experiment—the most familiar of the three being the Italian Navy Coherer gifted to him by Lt. Luigi Solari (see Fig. 31). In his speech to the Royal Institution in London on June 13, 1902, Marconi referred to these detectors as "microphonic self-restoring coherers."<sup>55</sup>

The term "microphonic coherer" has an interesting etymology leading directly back to Hughes and the use of his microphones as the earliest form of radio detectors. Hughes originally used the term "microphonic joints" to refer to his microphone detectors and derivatives thereof, whether or not they were self-restoring, because they produced a noise in his earphones when tapped or otherwise mechanically disturbed just like a microphone. Lodge, after hearing of Hughes' work, applied the term "microphonic detector" to a broader class of devices in his book *The Work of Hertz*—not only including Hughes' microphonic joints, but

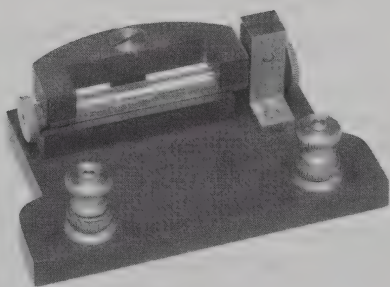


Fig. 31. Guglielmo Marconi used this Italian Navy Coherer with a single drop of mercury between a carbon and iron electrode gifted to him by Luigi Solari in his 1901 transatlantic experiment. (Science Museum/SSPL)

also the point-contact coherer Lodge claimed to have discovered, the iron-filing coherer of Branly, Minchin's impulsion cell previously mentioned, and the selenium cell (although he questioned whether or not the selenium cell should be included).<sup>56</sup>

The microphonic coherer invariably consisted of imperfect joints with very light contacts that produced a microphonic sound when tapped. Most also produced an echo in the response when excited with an electromagnetic wave. These devices were distinctly different than later crystal detectors that used a holder to apply pressure to the electrode contacts which not only made the devices less sensitive to vibration, but also eliminated the microphonic effects. For example, Greenleaf W. Pickard in particular was able to eliminate the microphonic sound by selecting combinations of materials that could be contacted with sufficient pressure to eliminate the microphonic effect. He characterized the best of his devices as having "perfect contacts"—as opposed to the microphonic joints (such as his detector made from carbon-blocks and steel needles) which he characterized as having "imperfect" contacts."

*What is a Self-restoring Coherer?*: Jagadis Bose was one of the first to discover and report on a self-recovering coherer in 1899 when he discovered that two electrodes of potassium retained their sensitivity after repeated exposures to electric pulses. He developed a theory that electric pulse caused the resistance of the contact to change for the duration of the pulse and then spontaneously return to its original value.

Due to lack of appropriate instrumentation, he was unable to

make transient measurements of the response of this device to spark discharge sources—only measurement of resistance before and after each exposure. He found that the pre-pulse and post-pulse resistances of the potassium contact were virtually identical, and so he represented what he believed to be the response of the potassium junction as indicated in Fig. 32.<sup>57</sup> Since potassium has the somewhat unusual property of exhibiting a *decrease* in conductivity when exposed to electric pulses, the conductivity is shown to decrease of during each pulse with a spontaneous recovery to the original conductivity after each pulse. Compare this to the response of a non-self-recovering coherer Bose found when measuring the response of a coherer consisting of iron electrodes (see Fig. 33). In the case of iron, the first exposure caused a dramatic drop in conductivity, followed by very small changes in conductivity when exposed to subsequent pulses.

The explanation of a temporary change in conductivity proved to be satisfactory until several experimenters noticed that the self-

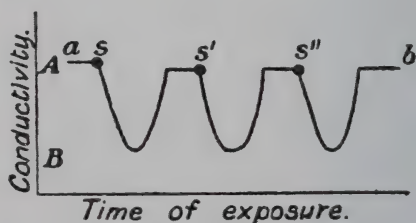


Fig. 32. Jagadis Bose believed the effect of radiation flashes (represented here by S, S', and S'') on his self-restoring potassium coherer was to produce a sudden diminution of conductivity followed by an automatic recovery such that conductivity "b" after each flash was equal to the initial conductivity "a." (Bose, *Collected Physical Papers*, 1927, p.151)

restoring coherer worked in the absence of an auxiliary battery, and so any explanation involving a change in conductivity alone could not explain an audible response in the telephone. This observation gave further support to a theory of a thermo-electric effect, one that had been postulated previously. According to this theory, each electric pulse heated the junction of the coherer, which in turn caused a thermo-electric current to flow in the external circuit without the need for a battery. This theory was supported by the observation that the magnitude of the d-c voltage produced in the junction was proportional to the square of the applied a-c voltage or current, implying a heating effect.

At the end of 1906, it was finally discovered that the crystal detector operated by the principle of rectification, but there appears

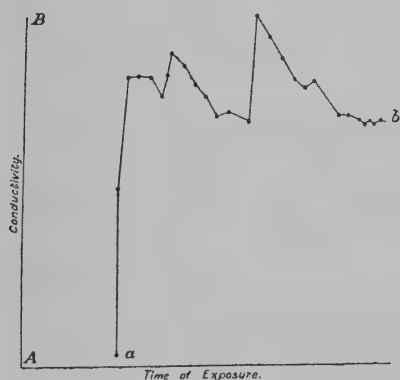


Fig. 33. In a non-self-recovering iron coherer, Jagidis Bose found that the first radiation flash dramatically increased the conductivity from "a" to a much larger value which is too great to be represented properly in the figure; there was no self-recovery after each subsequent flash (represented by dots), and the conductivity "b" after many flashes was still much greater than the initial conductivity "a." (Bose, *Collected Physical Papers*, p. 155)

to be no explanation in the literature of how the operation of the self-restoring or microphonic coherer differed from the crystal detector—if at all. Most historians continue make a distinction between the two categories detectors but do not state why.<sup>58</sup> The fact is that all self-restoring coherers—at least all those described in this paper—operate by the principle of rectification—just like the crystal detector. Nevertheless, there are some subtle differences as described below.

First, virtually all commercially successful crystal detectors used an elemental or mineral semiconductor for at least one electrode, whereas self-restoring coherers often used metal electrodes in which a thin oxide coating on one or both electrodes formed the semiconductor junction which produced rectification. The thin oxide coated was easily ruptured by applying excessive pressure, so the junctions of the self-restoring coherers were made with a light contact, which made for an unstable detector. By making one or both electrodes out of a semiconductor material, the dependence on a thin oxide coating was eliminated, and sufficient pressure could be applied to make the crystal detector stable with concern for penetrating a thin oxide layer. Virtually all crystal detectors used some type of mechanical device with a screw or spring to apply and/or adjust pressure on the electrodes, where as the self-restoring coherers generally depended on gravity—or in one case, a steady magnetic field—to make contact.

Second, the devices characterized as self-restoring coherers had lower breakdown thresholds than most crystal detectors, and as a result, the self-restoring coherer



often reverted to the classical coherer mode when the applied stress was larger than from normal operation—say, that produced by a lightning strike or a nearby high-power transmitter. As a result they often stopped working in the middle of a transmission, and had to be readjusted. For example, Marconi complained that the self-restoring Italian Navy Coherer he used in his 1901 transatlantic experiment was not useful for commercial work because it often became insensitive in the middle of a transmission (i.e., it reverted to the classical coherer mode as a result of a strong signal). This problem also occurred with certain crystal detectors such as the galena detector with a cat's whisker, which was often reported to become insensitive upon the reception of strong signals such as static and lightning, requiring a subsequent readjustment of the cat's whisker.

It should be noted that all coherers characterized as self-restoring operate in at least two modes: the rectification mode and the classical coherer mode. It is also interesting to note that classic non-restoring coherers can also be made to operate in the rectification mode as long as the applied electrical signal is limited in amplitude to levels below the breakdown threshold. This author and others have reported measurements of rectification by a variety of iron-filing coherers.<sup>59</sup> Another example of rectification by a non-restoring point-contact iron coherer was the foxhole radio used during WWII use to receive amplitude modulated signals by using the point of an iron safety pin pressed against a steel razor blade. Undoubtedly, it required frequent adjustment.<sup>60</sup> This version of the foxhole radio was slightly differ-

ent that the one referred to earlier in which the cat's whisker consisted of a carbon pencil point.

The reason for this can be explained as follows. The classic coherer is not an on-off switch, but instead has a range of I-V characteristics between the high-and low-impedance states. Certain of the I-V characteristics are both non-linear and quasi-stable, and can be readily accessed and used to rectify by properly adjusting the applied bias voltage. However, these modes are only quasi-stable and cease rectifying when they revert to the classic coherer mode, as they often do. Some coherers such as the iron-iron point-contact coherer do not require an auxiliary battery to access or operate in the rectification mode, while the iron-filing coherers virtually always do.

The self-restoring coherers can be divided in to two categories including a) point-contact devices with two electrodes in direct contact—one of which is generally pointed, and b) *multiple-contact* devices with two electrodes plus intervening matter in the form of carbon powder, crushed ball bearings, mercury drops, one or more needles that bridge the electrodes, etc. that provide multiple contacts with the two electrodes. Examples of the two types of self-restoring coherers which are notable from an historic viewpoint are listed in Table 1. Each of these coherers is briefly discussed in turn below.

*Hughes' Self-Restoring Coherers:* David Hughes was the first to discover at least three devices in 1879 that would later be characterized as self-restoring coherers by Munro in 1899. The crossed steel-carbon rod was a point-contact self-recovering device, while the iron-copper electrodes in a jar of coke, and the iron electrodes in

a jar of mercury constituted self-restoring multiple-contact devices. All three have been described and pictured previously.

*Brown & Neilson's Self-Restoring Coherers:* A. C. Brown and G. R. Neilson filed a British Patent Specification, No. 28,958, dated December 17, 1896 describing the use of carbon granules or powder in a coherer in combination with a telephone. Brown later stated that he had performed many experiments with carbon and found that it breaks down gradually so that the first exposure to a Hertzian wave will reduce its resistance slightly, the second will reduce its resistance still further, and so on until perhaps a dozen or so waves rendered it insensitive. At this point tapping was required to regain sensitivity. This device is historically significant in that it was the first mention of a device (after Hughes) which remained sensitive to multiple Hertzian wave pulses.

*Bose's Self-Restoring Coherers:* It appears that Jagadis Bose

was the first (again, after Hughes) to report a truly self-restoring coherer in his seminal paper "A Self-Recovering Coherer and a Study of the Cohering Action of Different Metals" presented to the Royal Society in April of 1899.<sup>61</sup> After experimenting with a number of metals, he found that potassium was an exceptional case that "*not only exhibits an increase of resistance by the action of radiation, but also a remarkable power of self-recovery.*" In his next paper he explained that the conductivity of potassium decreased during each exposure to electromagnetic radiation and returned to the original resistance after each pulse.<sup>62</sup> Presumably, the change in resistance produced a change in current in a circuit with a battery in series with galvanometer or telephone which produced a deflection in the galvanometer or tone in the telephone.

It turns out that his explanation was quite incorrect, and it would not be until late 1906 that it was understood that the con-

**Table 1. Historically Significant Self-Restoring Coherers**

Inventor	Year	Type
Hughes	1879	Steel-carbon, <sup>a</sup> Iron-copper-coke, <sup>b</sup> Iron-mercury-iron <sup>b</sup>
Brown & Neilson	1896	Carbon granules between electrodes <sup>b</sup>
Bose	1899	Potassium-potassium electrodes <sup>a</sup>
Tommasina	1899	Brass electrodes with a drop of mercury <sup>b</sup>
Popoff	1900	Carbon electrodes with a drop of mercury <sup>b</sup>
Castelli	1900	Crushed steel balls in a tube <sup>b</sup>
Solari	1900	Fe-Fe or C-C with a drop of mercury <sup>b</sup>
Solari	1901	Italian Navy Coherer (Fe-Hg-C) <sup>b</sup>
Bose	1901	Galena-Galena electrodes <sup>a</sup>
Shoemaker & Pickard	1902	Two carbon electrodes with five iron needles <sup>b</sup>
Massie	1904	Two carbon electrodes with one needle <sup>b</sup>

a) point-contact coherers;

b) multiple-contact coherers

ductivity actually oscillated about the operating point in accordance with the oscillating electromagnetic wave, and the imbalance in the conductivity during the positive and negative swings produced a net imbalance in the current—that is say, the oscillating signal was rectified. The battery was necessary only to adjust the operating point to a sensitive point on the I-V curve, but did not produce the resulting imbalance in current observed. For the next seven years Bose's erroneous explanation was accepted as one of the two possible theories by which self-restoring coherers worked.

*Tommasina's Self-Restoring Coherers:* Professor Thomas Tommasina, an Italian scientist well known for his researches in wireless telegraphy, communicated a note to *Comptes Rendus* on May 1, 1889 in which he described a very sensitive coherer consisting of a small drop of mercury situated between two brass electrodes of cylindrical shape—although he made no mention of the property of self-decoherence.<sup>63</sup> He communicated another note dated May 3, 1900 wherein he mentioned a self-decohering coherer consisting of a mercury drop between two carbon electrodes.

Tommasina's mercury-drop coherers are historically significant because, according to Luigi Solari who bequeathed the Italian Navy Coherer to Marconi, the coherers of both Corporal Paolo Castelli and Solari were based on Tommasina's work.<sup>64</sup> While Tommasina did not state whether or not his mercury drop coherer with brass electrodes was self-restoring, this author has experimented with the brass electrodes with a mercury drop and found that such a coherer is both sensitive and self-restoring when a d-c

bias of between 0.3 to 0.6 volts is applied.<sup>65</sup> When properly adjusted, the sensibility threshold (i.e., the threshold of audibility) is only slightly less than a modern 1N34A diode. However, the device is very sensitive to shock and vibration, and subject to permanent coherence when exposed to signals generated from strong electromagnetic waves.

*Castelli's Self-Restoring Coherers:* Naval Captain Quintino Bonomo at Livorno, Italy planned to carry out a series of experiments between September 1900 and May 1901 with Marconi's wireless apparatus methods proposed by Popoff and Tommasina.<sup>66</sup> Corporal Castelli—an assistant signalman in the Italian Navy—persuaded Bonomo and his superiors to perform an experiment with telephonic reception using a tube of his own making.<sup>67</sup> The results using little tubes containing iron or carbon electrodes and one or two globules of mercury (illustrated in Fig. 34) were extremely sensitive and at the same time self-decohering.

These devices are historically significant because they formed the basis of the Italian Navy Coherer (described next), which Marconi used during his transatlantic experiment. Note that one of Castelli's coherers consisted of a small drop of mercury situated between two carbon electrodes—virtually identical to the configuration reported by Tommasina on May 3, 1900, three months before Castelli began his experiments.

*Solari's Self-Restoring Coherer:* Lt. Luigi Solari assigned to Navy facilities at Spezia, Italy performed wireless experiments using a self-restoring coherer almost identical to those of Castelli, although he claimed the design of



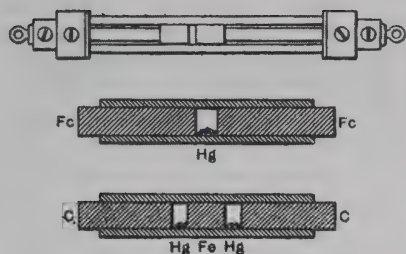


Fig. 34. Poalo Castelli's self-restoring and highly sensitive coherers consisted of a tube with one drop of mercury placed between two electrodes of iron, or two drops of mercury situated between an iron cylinder in the center and two carbon electrodes on the outside, both of which constitute a symmetric configuration. (A. Banti, *The Electrician*, June 27, 1902)

his tube was independent of Castelli.<sup>68</sup> However, since Castelli yielded his best results by February 20, 1901, while Solari initiated his experiments in January of 1901 and completed them in the summer of the same year using a tube almost identical to those of Castelli, there was a general suspicion that Solari's coherer was copied from one or more of Castelli's. The only real difference between the Solari coherer one of Castelli's coherers was that Solari had placed a drop of mercury between one iron and one carbon electrode, whereas Castelli had placed a drop of mercury between two carbon electrodes (see Fig. 35).

Solari gifted the coherer to Marconi in the summer of 1901, which Marconi used in his transatlantic experiment in December of 1901. After the experiment, Marconi disclosed in a speech to Royal Society he had used the Italian Navy Coherer and two other "microphonic" coherers—a term referring back to Hughes self-recovering carbon-based coherers of 1879.<sup>69</sup>

Marconi's use of these self-restoring coherers popularized these devices and the term self-restoring coherer. In the same speech Marconi also stated:

*"These non-tapped coherers have not been found to be sufficiently reliable for regular or commercial work. They have a way of cohering permanently when subjected to the action of strong electrical waves or atmospheric electrical disturbances, and have also an unpleasant tendency towards suspending action in the middle of a message."*

In fact, previous experiments performed by this author on mockups of the Italian Navy Coherer clearly show that the Italian Navy Coherer configuration is "self-recovering," but only over a limited range of applied voltages.<sup>70</sup> If the voltage produced by a electromagnetic signal exceeds a given threshold, typically a few volts, this coherer reverts back to the more familiar coherer mode where the conductivity greatly increases and where tapping back

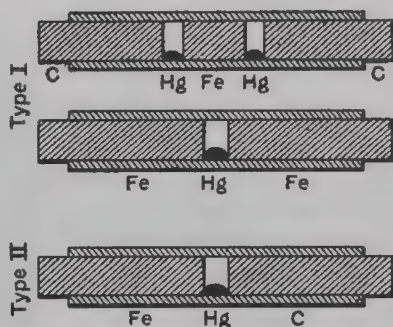


Fig. 35. Luigi Solari's self-restoring coherer with a drop of mercury situated between one carbon and one iron electrode, denoted here as Type II, was remarkably similar the second of two coherers made by Castelli, denoted here as Type I. (A. Banti, *The Electrician*, July 11, 1902)

is required to regain sensitivity. It takes some effort to get the coherer out of the coherer mode and back into “self-recovering” mode—which, like that of Bose’s self-recovering potassium coherer, is actually the rectification mode. As an aside, a third mode of operation was observed in the experiments with mockups of the Italian Navy Coherer—namely the repetitive-pulse mode which Lodge also observed in 1897, as described earlier in this article.

**Popoff’s Self-Restoring Coherer:** In March 1900, Alexander Popoff applied for a patent (U.S. 722,139) on a self-decohering device consisting of tube filled with ordinary polished steel beads of commerce crushed to expose various degrees of oxidation on their surfaces (see Fig. 36). This device was used in a receiver manufactured by Ducretet and used extensively by the Russian Navy (see Fig. 37).<sup>71</sup> Popoff’s self-restoring coherer is historically significant because, with a filing date of March 8, 1900, it is the first self-restoring solid-state coherer for which a patent was applied—pre-dating Bose’s patent application dated September 30, 1901 for a device he characterized as a self-restoring coherer/detector by more than a year.

It is somewhat ironic that Popoff should have received a patent for his self-restoring coherer, because, as mentioned previously, virtually all iron-filing coherers operate in a

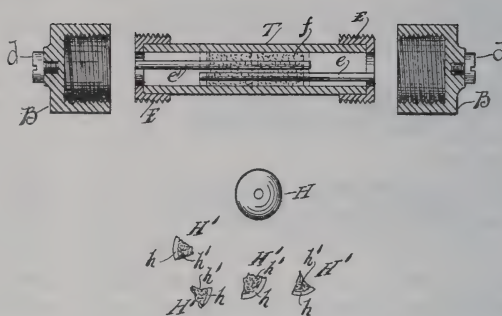


Fig. 36. On March 8, 1900, Alexander Popoff filed for a patent on a self-decohering system consisting of tube with two electrodes, (e), filled with ordinary polished steel beads of commerce, (H), crushed to expose various degrees of oxidation on the surfaces of individual fragments, (H'). (U.S. patent 722,139)

self-restoring mode in addition to the classic coherer mode. The rectification mode can be readily accessed by exposing the iron-filing coherer to a modest electrical signal first—sufficient to reduce the impedance modestly, but not to

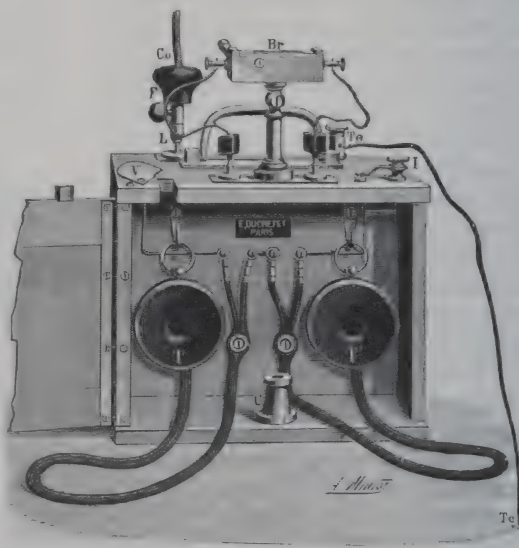


Fig. 37. Alexander Popoff’s self-restoring coherer was manufactured by Ducretet in France and used extensively by the Russian Navy. (D. Mazzatto, *Wireless Telegraphy and Telephony*, 1906 pp. 185)

the lowest impedance state where it becomes totally insensitive. This author has tested a number of iron-filing coherers and found they all operate in a self-restoring mode which is actually the rectification mode. The results for one such coherer were reported previously.<sup>72</sup>

*Bose's Galena Coherer/Detector:* Jagadis Chandra Bose filed a patent on a solid-state point-contact diode detector (U.S. 755,840) bearing an application date of September 30, 1901 (see Fig. 38). In his patent, Bose repeatedly characterized his detector as a "coherer or detector" rather than just a coherer or self-restoring coherer—as others before him had done. It must have been evident to him after years of studying coherers that his galena device was not the same class as other coherers, but it is clear that he did not understand that it was a rectifier of Hertzian waves.

Bose's patent has often been described as the first for a solid-

state point-contact crystal detector, and while this may be true, he was certainly not the first to discover such a device. That honor goes to David Hughes who first discovered and disclosed the steel-carbon point-contact crystal detector in 1879. In fact, it is somewhat surprising that Bose was granted this patent in 1904 because of such a broad independent claim:

*"1. In a coherer or detector of electrical disturbances, Hertzian waves, light waves, or other radiations, a sensitive substance having a characteristic curve...., which is not straight but is either convex or concave to the axis of the electromotive force and in which the return curve with a decreasing electromotive force when taken slowly, approximately coincides with the former curve."*

While David Hughes did not characterize his detector of Hert-

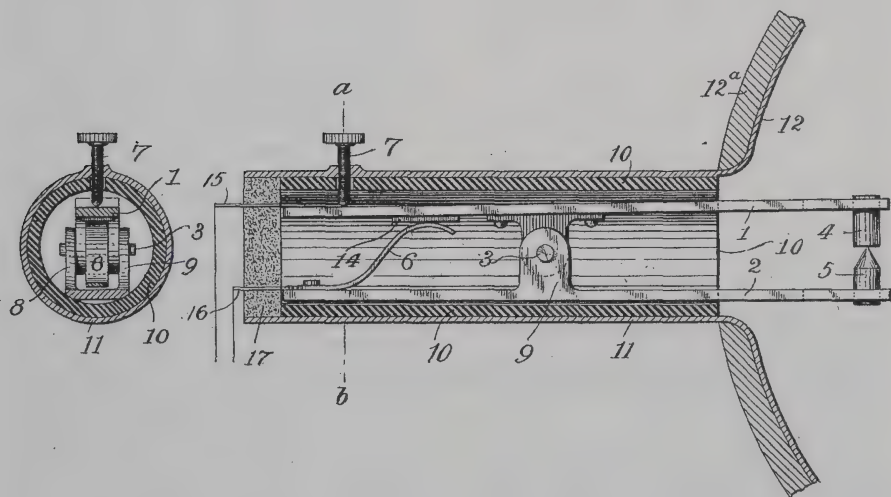


Fig. 38. Jagadis Bose filed a patent on a self-restoring coherer/detector consisting of two opposing galena electrodes—one of which was beveled to a point and the other flat—and both held in contact by a leaf spring with a thumb screw to adjust the electrode pressure. (U.S. patent No. 755,840)



zian waves as having a concave or convex characteristic curve, in fact, his device did have a concave characteristic curve just like Bose claimed in his patent—and as Louis Austin demonstrated several years after Bose's patent was issued.<sup>73</sup> If Bose's patent had been challenged in court, it most likely would have been invalidated as overly broad—or, given the patent office's later-demonstrated propensity to allow a patent for each different type of crystal detector, it might have been modified to cover only the galena-galena junction identified in a dependent claim of Bose's patent.

Apparently, no one has ever called attention to the fact that Bose's patent specifies a galena-galena junction, which because of its symmetry, requires a bias battery for detection. Such a configuration was never used in practice because asymmetric configurations such as galena and a cat's whisker of iron or copper worked very well without a bias battery. The fact that one electrode was pointed and the other was flat makes it no less symmetric, a point that W. H. Eccles made when he studied the galena-galena diode:<sup>74</sup> *"The efficiency of the detector is the same for each direction of the current, and appears to be practically independent of the shape of the galena surfaces at the contact."* He further stated: *"It was put into a wireless telegraphy receiving set and was found to yield excellent signals when a current of proper magnitude [i.e., a d-c bias] was passed through it."*

*Shoemaker & Pickard's Self-Restoring Coherer:* On June 2, 1902, Harry Shoemaker and Greenleaf Pickard filed for a patent on *"a wave-responsive device comprising carbon terminals bridged by metallic needles,"*

which was assigned to the American Wireless Telephone and Telegraph Co. (U.S. 707,266). Their patent made dependent claims for steel as the preferred metal for the needles. The specification also stated that the device had the *"property of great delicacy and sensitiveness in responding to electrical radiations and has also the desirable property of retaining its normal condition after the cessation of influence of electrical waves,"* which is to say it was self-restoring. Pickard referred to this device in his notes as a coherer, because it was still not known at this time that the carbon-steel device worked by the principle of rectification.

Their invention was not for a single needle—which was already in the public domain as a result of Hughes' work—but rather with claims for five needles resting on two carbon blocks which paralleled each other to assure that at least one junction would be sensitive at any given time, and also with claims for a tilting platform upon which the carbon blocks rested so that the sensitiveness of all could easily be altered by tilting the platform (see Fig. 39).

It should be noted that Pickard never claimed to have invented this device himself, and given the fact the Shoemaker's name was first on this patent and that Shoemaker had already filed a patent on a self-restoring coherer a few months prior (U.S. 700,708), it is safe to assume that Shoemaker was the principal inventor. In sworn testimony during a later patent infringement suit Pickard claimed only to have become familiar with the device—not invent it: *"In 1902, while engaged with the early wireless interests aforesaid [American Wireless] I was employed, among things, in the*

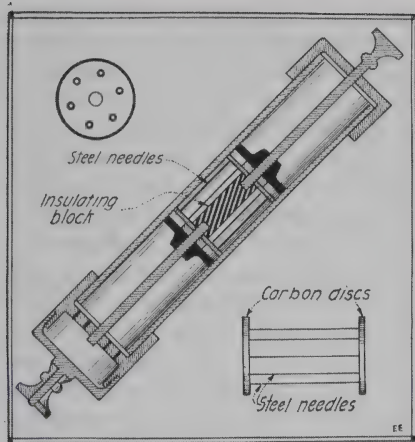


Fig. 39. Harry Shoemaker and Greenleaf Pickard filed a patent on a self-restoring coherer consisting of five steel needles constrained by five holes drilled in two circular carbon electrodes arranged such that the entire detector assembly could be tilted to alter the pressure of the needles against the carbon electrodes. (*Electrical Experimenter*, Aug. 1919, p. 325)

*experimental development of detectors for wireless telegraphy, and became familiar with the construction and use of contact detectors of the carbon-steel type, employing a local battery...."*

Pickard used this device at the Cape May station in 1902 while

he was employed by American Wireless, and according to Pickard's recollections it was directly responsible for inspiring him to search for more sensitive materials and better contacts for radio detectors—ultimately leading to his discovery of the silicon detector in 1906. His search for the “perfect contact” is chronicled in a following section.

*Massie's Carbon-Steel Oscillaphone De-*

*tector*: The self-restoring carbon-steel detector required a rather light contact pressure and was therefore subject to degradation in performance from effects of vibration and motion which might be found aboard ships. Massie designed the carbon-steel Oscillaphone detector to operate in such environments. It consisted of a steel needle across two carbon blocks—not unlike one of the detector elements in the Shoemaker-Pickard patent, except that it also included a permanent magnet which served to hold the needle in solid contact with the upper edges of the carbon terminals. Massie filed for two separate Oscillaphone patents, the first with a filing date of July 14, 1904 (U.S. 760,005) in which the magnet was situated adjacent to the needle, and the second with a filing date of Aug. 18, 1905 (U.S. 819,779) in which the magnet was situated below the needle (see Fig. 40). In both cases, the purpose of the magnet was not to restore sensitivity, but rather to keep the needle in firm contact with the carbon.

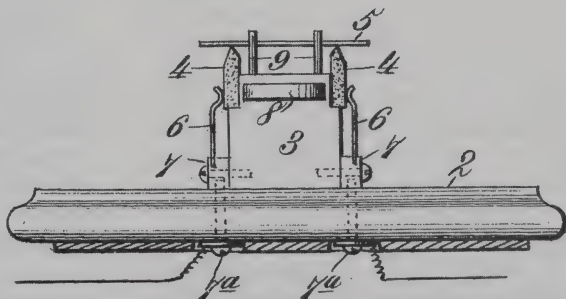


Fig. 40. Walter Massie filed his second self-restoring Oscillaphone detector patent consisting of a steel needle [5] resting across two carbon blocks [4] with a permanent magnet [8] to secure the steel needle to the carbon blocks and prevent unwanted displacements. (U.S. patent No. 819,779)

## THE SWING TO AURAL RECEPTION AND THE ADOPTION OF THE CRYSTAL DETECTOR: (1901-1906)

The beginnings of aural reception can be marked by Marconi's use of Marconi's three microphonic detectors in his December 1901 transatlantic experiment, and the full transition to aural reception can be marked by the adoption of the crystal detector in 1906—although the adoption of aural reception in wireless systems actually had little to do with the crystal detector itself. Perhaps the first to use the telephone in a wireless system was DeForest with his so-called responder in 1901. Other's were not far behind—Marconi with the magnetic detector, and Fessenden, Schlömilch (Germany) and DeForest with electrolytic detectors—all in the 1903-4 time frame.

While the swing to aural reception was underway, the single point-contact crystal detector was slowly and quietly evolving into a practical device suitable for use in wireless telegraphy systems. Alexander Popoff was the first to file a patent for a self-restoring coherer on March 8, 1900 which was issued on March 3, 1903 (U.S. 722,139), while Jagadis Bose filed a patent on a self-restoring galena-galena coherer/detector on Sept. 30, 1901 which was issued on Mar. 29, 1904 (U.S. 755,840).

The crystal detector burst onto the scene in 1906 with five different patents filed and/or issued that year on devices that would later become known as crystal detectors, and the crystal detector itself would be found to operate on the principle of rectification by the end of 1906. The five patents filed or issued in 1906 are as follows: 1)

Walter W. Massie with U.S. patent No. 819,779 filed on Aug. 18, 1905 and issued on May 8, 1906, 2) Ferdinand Braun with German patent No. 178871 filed on Feb. 18, 1906 and issued on Oct. 22, 1906, 3) Henry H. C. Dunwoody with U.S. patent No. 837,616 filed on Mar. 23, 1906 and issued on Dec. 4, 1906, 4) Louis W. Austin with U.S. patent No. 846,081 filed on Oct. 27, 1906 and accepted on March 5, 1907, and 5) Greenleaf W. Pickard with U.S. patent No. 836,531 filed on Aug. 30, 1906 and issued on Nov. 20, 1906.

Not surprisingly, the individuals who filed the above-referenced patents were also the ones who contributed more to the development and adoption of the crystal detector than others like George Pierce, who was responsible for popularizing the crystal rectifier name and demonstrating conclusively that the crystal detector operated by the principle of rectification in 1907. He also applied for a crystal detector patent made from the crystal hessite and a compound of silver and tellurium in 1907 (U.S. 879,117), but it cannot be said that he was responsible for the development or adoption of the crystal detector.

The activities of the key individuals who contributed to the development of the crystal detector during the period 1901-1906 are recounted in the remainder of this section. With the notable exception of the Pickard/Dunwoody nexus, the developments were clearly independent of each other. Their activities are summarized below in chronological order rather than in the order of the importance of their contributions. The contributions of David Hughes have been addressed previously and are not included here. It was David Hughes who actu-



ally discovered the point-contact crystal detector in 1879, but unfortunately he died on January 22, 1900 and never saw the adoption of his invention by the major telegraph companies. Building on Hughes' steel-carbon detector, Pickard developed the crystal detector into a form that was particularly suitable for commercial telegraphy, and he was almost singularly responsible for the adoption of the crystal detector by most commercial and government wireless telegraphy systems in the U.S.—and many abroad, as well.

*Contributions of J. C. Bose:* Jagadis Bose discovered his first self-restoring point-contact coherer in 1899 using potassium electrodes, and later experimented with other combinations of elements and compounds that also resulted in self-restoring coherers. Most of his experiments with coherer were intended for the purposes of understanding how coherers worked rather than for the purpose of developing coherers suitable for wireless telegraphy. With the notable exception of his galena detector, he never specified any of the parameters that would have been critical to the design of a practical coherer—electrode shape and dimensions, method or methods of achieving reliable contacts, bias voltages, sensitivity or sensibility thresholds, etc. Further, many of the materials he used such as potassium, which reacts vigorously with water or water vapor, would have been unsuitable for wireless telegraphy applications.

In May of 1901, Bose first mentioned experiments with an electric eye using galena in which he disclosed that “*the eye recovers without external aid*” after being exposed to electric radiation.<sup>75</sup> He went on to say: “*This will show*

*the possibility of an automatic receiver which will record Hertzian wave-messages without the intervention of the crude tapping device.*” This is perhaps the first and only time in his published works (excluding his galena patent) that Bose mentioned wireless telegraphy as a possible application for one of his self-restoring coherers. It is also the first time he reported experimenting with a naturally-occurring crystalline mineral as opposed to elemental metals or compounds he prepared.

Bose mentioned galena one more time in June 1901, but only in passing, and he never presented any data on the response of a coherer which he identified as galena. However, in September of 1901, Bose did present the I-V characteristics for an unidentified self-recovering coherer and stated that he “*was not prepared, however, for results so remarkably perfect*”—which was an indication that the self-recovery properties of the coherer was also equally perfect. It was unusual, to say the least, that Bose did not identify the material in this paper, as he had done for every other response curve he had presented up to this point.

In light of his galena patent with an application date of Sept. 30, 1901, it became clear that the unidentified device described in his paper was the self-recovering galena coherer/detector described in his patent. The device described in his patent was indeed a strange electric eye configuration for which he claimed applications to sensing both light and Hertzian waves. From the lack of detail in his September 1901 paper and the fact that he never mentioned this device again in any of his subsequent technical papers, it is clear

that it was his intent not to disclose this device until his patent issued, probably on the advice of his attorney—something that appeared to be the norm at that time. When Bose's patent finally issued on March 19, 1904—thirty months after its filing date—it went virtually unnoticed by the scientific community.

There were few if any references to Bose's galena detector in the contemporary literature following the publication of his patent. About the only mention of his patent was by Geddes in his book *The Life and Work of Sir Jagadis C. Bose* published in 1920 where he makes the following claim for Bose's galena detector: "*The invention of a new type of self-recovering electric receiver was the forerunner of the application of crystal detectors for extending the range of wireless signals.*"<sup>76</sup> In fact, even this statement was not true. In light of David Hughes' discovery years before of the steel-carbon detector, it was not a new type of self-recovering coherer. Also Hughes' crystal detector was the direct forerunner of the crystal detectors used in wireless telegraphy—not Bose's. To this author's knowledge, Bose's galena-galena coherer was never used in wireless telegraphy, and further there is no evidence that his device was responsible in any way for the adoption of the crystal detector in wireless telegraphy.

One can image at least three reasons why Bose's galena-galena detector made virtually no impact on the development or adoption of the crystal detector. First, after receiving his patent, Bose never pursued any commercial application of this device himself. Worse yet, by all accounts Bose refused to license his device to others such

as such Alexander Muirhead, who had expressed great interest in Bose's new detector.

Second, Bose's symmetric galena-galena electrode configuration required a bias battery to achieve a reasonable level of sensitivity, while Pickard and others soon discovered that galena worked just as well without a battery when dissimilar materials such as a metal wire or other crystalline materials were used as the second electrode. As a result, a number of pyrites including galena in combination with other electrode materials began to appear in crystal detector patents and in wireless receivers. It is unlikely that Bose could have claimed infringement by those who used only one galena electrode—even if he were inclined to do so, which he was not—because galena, per se, had been identified by Braun in 1874 as a material that had the same nonlinear I-V characteristic curves that Bose had claimed in his patent, and Bose failed to include any dependent claims for a single galena electrode in combination with other types of electrodes.

Third, by the time Bose's patent had issued in March of 1904—30 months after he filed his application—the major wireless companies had already transitioned from the coherer to other technologies such as the magnetic detector and the electrolytic detector, while a few of the smaller companies had selected the carbon-iron needle microphonic detector patterned after the discovery of Hughes, a version of which was patented by Shoemaker and Pickard in 1902 and popularized by the American Wireless Telephone and Telegraph Co. addressed in the next section. Also, by March 1904, three pat-

ents had already been issued for self-restoring coherers which were actually rectifying detectors—Shoemaker (U.S. 700,708), Shoemaker/Pickard (U.S. 707,226) in 1902, and Popoff (U.S. 722,139) in 1903—and so Bose's patent, which was repeatedly characterized in his patent as self-restoring "coherer or detector," would not have received much attention.

*Contributions of F. Braun:* While Braun discovered the non-linear I-V characteristic of various imperfect contacts including galena and psilomelane in 1874, he did so at time before radio waves had been discovered, and so his work at that time made no direct contribution to the radio detector. According to the paper he wrote in 1906, it was May of 1901 that he performed his first experiments demonstrating that psilomelane could be used with a telephone to produce clear sharp sounds when small fast oscillations were fed into the circuit. However, these results were never disclosed—and not even mentioned in public until December 1906, and so clearly they could not have made any contribution to the development of the crystal detector by others before 1906 nor the or adoption thereof in 1906.

In the same paper, Braun claimed he took up the psilomelane detector experiments once again in December of 2005 with his assistant, one Mr. Hermann Brandes. This assertion is supported by the fact that Braun filed a patent in Germany with an application date of February 18, 1906 making claims for a psilomelane crystal detector, while his associates W. Schlömilch and P. F. Pichon filed a patent (U.S. 962,262) in the U.S. with a filing date of April 14, 1906 making essentially the same claims.

These were the first, and possibly the last, public disclosures by Braun of solid-state detector designs for wireless telegraphy.

Clearly, Braun's disclosures in December of 1906 did not have any influence on Bose, who filed his galena patent years before, and it will be seen in the next section that Braun's disclosure also could not have had any effect on Pickard's and Dunwoody's work. Further, the crystal detector was not introduced into German wireless systems until well after its introduction into wireless systems in the U.S. in 1906, so it cannot be said that Braun's work had much effect, if any, on the introduction of the crystal detector into wireless.

*Contributions of G. Pickard:* Much of what is presented here has been taken from the sworn testimony of Greenleaf W. Pickard and numerous witnesses taken during the course of a consolidated patent interference action by the U.S. Patent Office circa 1910, as well as from Pickard's Original Notes from May 29<sup>th</sup> 1902 to August 28<sup>th</sup>, 1906 produced by Pickard specifically for this action.<sup>77</sup> Because this information was produced under penalty of perjury and was tested by opposing counsel through the process of cross examination, it is likely to be at least as reliable as any other source.

According to Pickard, he began his investigations in wireless detectors leading to the discovery of many crystal detectors on May 29, 1902 while receiving messages at the Cap May, N. J. station of the American Wireless Telephone and Telegraphy Co. using the "Carbon-Steel" Microphone Detector—as he referred to it—that he and Shoemaker had patented as described previously. It is





Fig. 41. Greenleaf W. Pickard developed the crystal detector into a form that was particularly useful for commercial telegraphy, and was almost singularly responsible for the adoption of the crystal detector by most commercial and government wireless telegraphy systems in the U. S.—and many abroad, as well.

worth noting that in an article written in 1919, Pickard specifically tied this carbon-steel microphonic detector to the early work of David Hughes.<sup>78</sup> While receiving messages on May 29, 1902 at Cape May, Pickard accidentally discovered that messages continued to be received by this detector even when the battery was taken out of the circuit. This event was recorded in Pickard's notebook, as shown in Fig. 42. Pickard's note clearly states: *"Cutting out battery entirely, faint signals could be heard, even at ten miles were loud enough to be read."*<sup>79</sup> This struck Pickard as extraordinary, and contrary to the theory as he understood it, and contrary to all his previous practice, as well as. His statement regarding the con-

ventional theory at that time supports the fact that the theory of rectification was unknown:

*"The explanation of the action of the carbon-steel detector using the battery, as known me at that time, was that it was simply a self-restoring microfone [sic] wherein the signals were caused by momentary resistance-variation at the contact, which varied the current in the battery-circuit and caused sounds in the telephone which corresponded to the Morse code dots and dashes of the transmitter messages."*

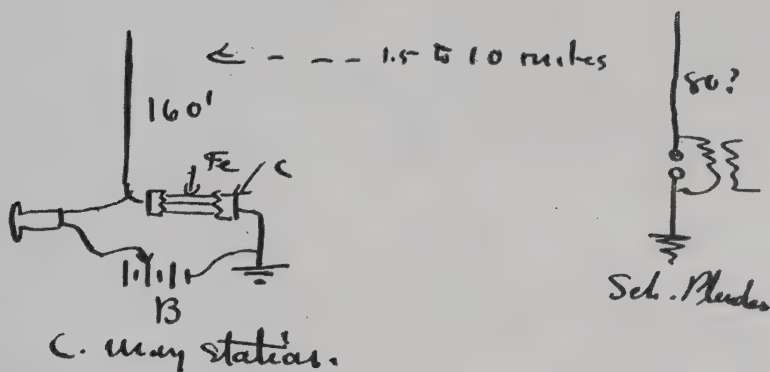
As a result, Pickard was determined to *"thoroughly investigate the phenomenon and endeavor to discover the conditions most suitable to its useful employment, and to adapt and perfect detectors embodying this apparent novel principle of operation, whatever it might be."*

Pickard left American Wireless soon thereafter, joining AT&T on July 1, 1901, where he was employed until June of 1906. His first assignment was to develop and demonstrate a wireless system for voice transmission and reception, something coherers could not do. He succeeded in doing so by September 6, 1902 as evidenced by a schematic of his demonstration unit which he recorded and dated in his notebook, a feat which was chronicled much later in the September 1922 issue of *Popular Science*.<sup>80</sup>

During this period, Pickard experimented with a large number of carbon-steel and steel-steel configurations based on the device he and Shoemaker had patented while at American Wireless, as well as devices using several different types of carbon granules. It was during this period he discov-

May 29/02

## Carbon-Steel Detector.



Good signals with battery  $\approx 3$  v.  
cutting out battery entirely, faint  
signals could be heard, even at 10 m.  
were loud enough to read.

Fig. 42. Greenleaf Pickard's notebook entry dated May 29, 1902 memorialized the date he first learned that a self-restoring coherer could function without any battery: "Cutting out battery entirely, faint signals could be heard, even at ten miles were loud enough to be read." (Pickard's personal notebook entry dated May 29, 1902)

ered that both contact pressure and a small contact area were critical to the performance of these detectors. Pickard's first solution to achieve both conditions simultaneously was to use a spring contact using a fine wire in which the pressure could be easily adjusted (and manufactured cheaply) as indicated by the drawing in his notebook dated July 18, 1902 (see Fig. 43). Thus, Pickard was one of the first, if not the first, to invent and use what later be-

came known as the "cat's whisker."

Note the reference to a buzzer in the drawing that he used to excite the receiver consisting of a telephone and his detector. He often excited his detectors with a 6-volt buzzer, something that later became standard on commercial crystal sets in the early 1900's. Also, note that he continued to refer to his detectors as coherers—as was customary at the time—even though he was well aware

July 18<sup>th</sup> 1902

Carbon coherer -

(see 17<sup>th</sup>)  
With small buzzer, this  
worked well at 5-m distance,  
through a wall and cup-  
board of drawers filled  
with metallic instruments  
as below -

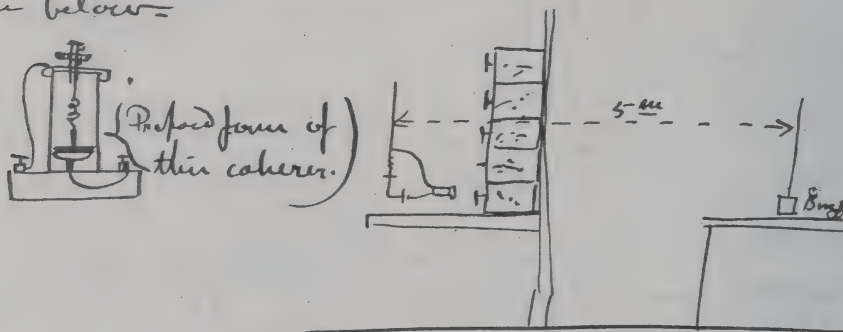


Fig. 43. Greenleaf Pickard's notebook entry dated July 18, 1902 documents the first recorded use of a cat's whisker as an electrode for a detector: "spring of fine copper wire," and also the use of a buzzer to test the sensitivity of the detector: "with small buzzer this worked well at 5 m distance." (Pickard's personal notebook entry dated July 1902)

that it did not operate with the usual "trigger action" of the classical coherer. In an Oct. 16, 1902 entry in his notebook, Pickard stated "It is probable that the carbon steel [junction] acts as a thermo-element, and the heating caused by the Hertzian waves generates slight currents which reproduce the sound in the receiver."

Another discovery that Pickard emphasized in two notes dated Aug. 20, 1902 was the existence of a specific battery voltage for the carbon-steel that produced a

maximum effect—that is to say that voltages greater or less than this value produced a smaller effect. Unbeknownst to Pickard at the time, this bias voltage corresponded to the "knee" of the I-V curve where the rate of change of conductivity with respect to bias voltage was greatest.

By the end of 1902, American Telephone (AT&T) decided not to pursue wireless telephony further, and so Pickard's detector work at AT&T all but stopped. Since he had no laboratory in his home at that time, there was a hiatus in



his detector work in the period between December 1902 and December 1904, as reflected by the reduction of entries in his notebook to only a few. Pickard moved to his family home in Amesbury, MA in September of 1903 and began to build his own detector lab there in June 1904. Several commercial wireless stations came into range in the later part of 1904 and 1905, and Pickard himself built a radio station at his home in December 1904 with the call letters HY, which coincided with a flurry of activity in his experimentation as reflected by numerous entries in his notebook beginning on December 14, 1904 and continuing through 1906 and beyond.

Most of Pickard's detector work during 1905 was confined to experiments with oxides of common elements, only a few of which were naturally occurring minerals such as magnetite (an oxide of iron)—even though he was then in possession of a mineral collection from his father which included iron pyrite, chalcopyrite, galena, pyrolusite or manganite and magnetite.

By October of 1905, Picard had not yet discovered any detectors of historical import, but he did write the following note which summarized the status of his knowledge and work.

*"October 8/1905.  
Wireless Telegraphy  
Detectors*

*"There are at least two lines on which commercial detectors may be constructed, and which do not involve any relay, or trigger action."*

- a. Rectifier detectors
  1. Vacuum tube,
  2. Electrolytic cells
- b. Thermo-couples

*"The small current flow and relatively high E.M.F. of vacuum tube rectifiers is a disadvantage; high temperature, and suitable electrode material may obviate this.*

*"Electrolytic rectifiers, such as the Pupin, are distinctly operative, but which require aux. [auxiliary] source of voltage, and, for this reason, would be infringement of Fessenden (?).*

*"Thermo-couples can be made of sufficient sensitiveness for commercial work, and probably stable enough. An occasional adjustment for new contact surface would be unobjectionable. Proper material will probably eliminate this. A fluid for one contact element would insure stability; insulation of other would keep area constant."*

This note is important for several reasons. First, it clearly shows that Pickard (and the entire scientific community, as well) recognized that both the vacuum tube and the electrolytic cell acted as a rectifier of Hertzian waves, but believed the coherer acted as a thermo-couple, not as a rectifier. Second, it clearly showed that Pickard believed these devices, which he characterized as "thermo-couples," would be suitable for commercial work, and that he understood the three requisites for commercial work consisted of sensitiveness, stability, and ease of adjustment. He even predicted that "proper materials" would be found which would eliminate the need for occasional

adjustment, and while he did find such a material with molybdenite, the government apparently chose not to purchase detectors made with it because of its relatively low sensitivity.

His first important discovery came on December 12, 1905 when he found that the combination of galena and pyrite made an extremely sensitive detector—in fact, one of the most sensitive detectors that he ever found. That month he also read about silicon in the *IEE Science Abstracts* and knew it would be a good candidate for a detector because of its high specific electric resistance and thermo-electromotive power, properties that were common to other materials he used to form the most sensitive detectors.<sup>81</sup> He immediately set out to purchase samples, a process that would take eight months. Before Pickard received the silicon samples, he was engaged by the American DeForest Wireless Telegraph Company in the spring of 1906 as a consultant to assist in developing a wireless detector made from carborundum, a compound that had had been recently discovered by H. H. C. Dunwoody. The development of the carborundum detector and Pickard's role in this development will be chronicled in the next section.

Shortly after finishing his work with American DeForest in the summer of 1906, he severed connection with AT&T, opened his own office in rooms of the Huff Electrostatic Separator Co., and began his extensive investigations and development of wireless detectors. His first discovery, and probably his most significant, was the silicon detector with which he first experimented on August 13, 1906, the same day he received his

first samples. He filed what would be his first of many detector patents on August 30, 1906, a mere 17 days later. Several months later on November 18, 1906, he found that zincite with a brass contact made good detector, and the next day he found that zincite with a chalcopyrite electrode formed an even more sensitive detector. He filed his first patent with a filing date of Sept. 30, 1907 for zincite with a brass electrode for which he used the trade name "perikon," a tortured acronym for **Perfect Pickard Contact**. A year later on Oct. 15, 1908 he filed a second patent for zincite and chalcopyrite. Both detectors became known as perikons in the trade.

In early 1907, the U.S. Signal Corps approached Pickard and purchased a quantity of silicon detectors. With the money he made from this sale he was able to expand his efforts. In the early summer of 1907, Pickard, Col. John Firth, and his patent attorney Philip Farnsworth formed the Wireless Specialty Apparatus Company for the purpose of selling the silicon and perikon detectors based on Pickard's designs, but gradually the Company extended their business line to complete receiving sets. Firth claimed the annual business circa 1911 amounted to "*many tens of thousands of dollars.*" Pickard describes the following detectors that were manufactured and/or sold to the trade in the four years from 1907 to 1911 as follows:

- *Silicon*: marketing began in 1907; fairly stable and easy to adjust but not as easy to adjust as the perikon; it was replaced by the pyron but made a comeback after it was made more stable;
- *Pyron* (fine wire against iron pyrite); sales beginning in

1909; greater stability than the original silicon detector, but not as sensitive;

- *Galena-pyrite*: sold primarily to the government beginning in 1910; very sensitive, and fairly stable and easy to adjust, but had the particular idiosyncrasy that it was not permanent chemically, and required frequent replacement after a few weeks use;

- *Perikon* (zincite with a wire, or zincite with chalcopyrite): marketed beginning in 1907-08; very sensitive and easy to adjust, but not very stable;

- *Molybdenite*: almost perfectly stable and fairly sensitive, but not up to Navy standards for sensitiveness.

Pickard assembled an interesting table of the relative sensitivity of the more important combinations of minerals and electrodes he

had discovered by 1911 reproduced here as Fig. 44. He rated the most sensitive combinations as 20 and the least sensitive combinations as 0. For example, the combination of galena and pyrite was the most sensitive, followed closely by the combination which Pickard trademarked perikon. By 1919, Pickard claimed to have tested several thousand materials for suitability as a radio detector:<sup>82</sup>

*"A list of the several thousand materials I have tested would make dry reading. Suffice it to say that I have found some two hundred and fifty minerals and furnace products which make operative detectors, either against metallic contacts, or in combination with other minerals. The possible combinations of these two hundred and fifty substances, amounting to some 31,250 pairs,*

	Se	Te	Si	SiC	CuSe	Chalcopyrite	Pyrite	Bornite	Galena	Marcassite	MoS <sub>2</sub>	Magnetite	Zincite	Stibnite	Pyrolusite
Se		5	11	4	0	8	8	6	2	0	12	5	3	0	8
Te			15	9	1	9	9	9	6	1	18	6	4	0	9
Si				5	2	5	5	7			10		12		11
SiC					0	10							6		
CuSe							0		1				1		
Chalcopyrite							18	0	10	2	15	3	15	0	12
Pyrite								10	20		6		11		8
Bornite									6		12	2	15		16
Galena											5	1	8	0	8
Marcassite															
MoS <sub>2</sub>															
Magnetite										0					15
Zincite															18
Stibnite															
Pyrolusite										NG				NG	

Fig. 44. Greenleaf Pickard prepared a table showing the relative sensitivities of various combination of the more important detector materials with the highest sensitivity arbitrarily set at 20 and the lowest at zero. (U.S. Patent Interference No. 31,649 circa 1911, p. 69)



*have all been tested by me or my assistants, and many hundred useful pairs have been found."*

Indeed, Picard's Wireless Specialty Apparatus Co. had assembled a list of detectors they had manufactured and sold by the early 1920's that runs into the hundreds of different "Type" models.<sup>83</sup>

*The Contributions of H. H. C. Dunwoody:* The American DeForest Wireless Telegraph Company had been using Fessenden's electrolytic detector in its wireless system, a detector DeForest candidly admitted stealing from Fessenden several years before.<sup>84</sup> After protracted patent-infringement litigation between Fessenden and DeForest, Judge Wheeler enjoined DeForest from further use or distribution of this detector in a relatively short opinion dated October 16, 1905. As a result, the DeForest was scrambling to find an alternative detector that would approach the sensitivity of the electrolytic detector. In the meanwhile, DeForest modified the electrolytic detector and continued to infringe on Fessenden's patents during the search for an alternative.

Sometime in early 1906, retired General H. H. C. Dunwoody discovered the compound silicon carbide—known commercially as carborundum—would act as a detector of radio waves. The circumstances of this discovery have never been documented, but it is known that Dunwoody filed a patent application with an application date of Mar. 23, 1906 (837,616). Pickard shed some light on the circumstances of Dunwoody's discovery in a letter he wrote to Dr. L. S. Hillegas Baird, who was seeking firsthand information from a number of wireless pioneers in 1950:<sup>85</sup>

*"As to General Dunwoody, I am afraid I can contribute but little. I met him just once, sometime in the summer of 1906, and after a half-hour talk found that he knew little about radio, but had discovered by pure accident that carborundum would act as a detector."*

That Dunwoody knew little about radio was apparent from the naïveté displayed by the detector configurations shown in his patent. A number of different ways of connecting electrodes to the carborundum crystal are shown in his patent specification, but the most interesting from an historical perspective is the one known as the "fire-cracker" shown in Fig. 3 of the patent, a reproduction of which is shown here as Fig. 45. This configuration was introduced into the American DeForest system in the middle of the spring of 1906 before it was properly engineered and tested—almost certainly as a result of a second injunction from Judge Wheeler dated April 7, 1906 prohibiting the Company from further use of the electrolytic detector.

This configuration did not work, and its premature introduction into the American Wireless system almost caused the demise of the Company. H. J. Hughes, Chief Operator for the American DeForest Company at the time, put it this way under oath circa 1911 in the previously mentioned interference action:

*"About the middle of the Spring of 1906 the carborundum detector was put into the Company's service in the form known as the 'fire-cracker' of which Pickard Mechanical Exhibit 15 is a sample. This exhibit is partially cut away*



Fig. 45. Henry Dunwoody's "fire-cracker" configuration appearing as Fig. 7 of his patent U.S. patent No. 837,616 has been recreated here showing copper leads wrapped around either end of a conglomeration of carborundum crystals (without the wax applied to keep moisture out or the protective enclosure consisting of a fiber shell and brass endcaps), which was unsuccessfully deployed by American DeForest and almost caused the demise of the Company.

so as to show the carborundum inside with a wire wrapped around the bunch of carborundum crystals, and the same covered with some substance, as wax, to keep out moisture. In this form the carborundum detector had proven to be entirely inadequate for the Company's service, and Mr. Pickard had been called upon by reason of his well-known special knowledge of such matters to see what he could do toward improving it. I know that at the time Mr. Pickard was engaged in showing the Company's operators and engineers how to improve the carborundum detector, which in the 'fire-cracker' form was not only not very sensitive but not at all stable, and had no means by which it might be replaced in operative condition when once put out of adjustment from any cause."

Cloyd Marshall, another employee of American DeForest in 1906, provided further insights

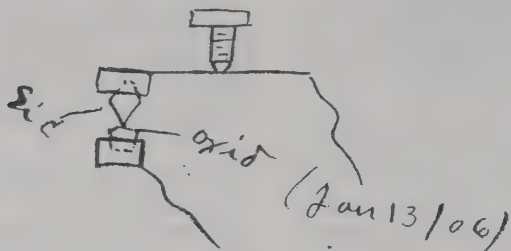
through his sworn testimony into the functioning of the fire-cracker version of the detector as well as Pickard's contribution:

*"When the carborundum was put into the company's service in the form of the so-called 'fire-cracker' detector, Pickard Mech. Ex. 15, it was so universally condemned by all the operators that the company's officers and engineers felt the carborundum was a failure as a wireless detector. The reason for that is now apparent, from Mr. Pickard's showing that it was impossible to make a successful detector with carborundum crystals having large contacts such as are found in his type of holder. It is my belief that Mr. Pickard was responsible for discovering, at least revealing to the operators and engineers in the company's employ that a small point of contact at either end or at least at one end of the crystal was desirable, and that there should be some sort of adjustment or pressure on this point of contact in order to make the carborundum satisfactory as a detector. This was accomplished by means of the detector holders of Pickard Exs. 16 and 18."*

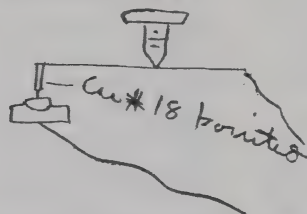
Pickard testified that he supplied the design for the form of crystal holder which was subsequently used by American DeForest: "Doc. Ex. 34 is Mr. Babcock's patent for the form of holder which I disclosed to him in May, 1906 as my design, this being the device of my notes dated May 7, 1906, which I made on May 6, in Amesbury." By comparing Pickard's notes dated May 7, 1906 shown in Fig. 46 with the detector pictured in the patent (U.S. 901,942) filed by American DeForest engineer Clifford

Wireless Telegraphy  
"Arc" coats - Carborundum

May 7/06



Ti, Fe, Zn, & Cd not so good as  
metal with SiC



Zn & Cd best with no. battery  
but Fe gave 15% increase with  
6/10 volt; Ti 20% with 1.1 volt.

Fig. 46. That Greenleaf Pickard actually designed the carborundum crystal detector successfully introduced into the American Deforest company is evident from the sketch in his personal notebook dated May 7, 1906—which clearly formed the basis for Clifford Babcock's patent filed on Aug. 27, 1906 (compare with Fig. 47). (Pickard's personal notebook entry dated May 7, 1906)

Babcock (see Fig. 47), it is obvious that Babcock appropriated Pickard's design with out credit and claimed Pickard's work as his own. Indeed, H. J. Hughes confirms Pickard's account in sworn testimony:

"I understood at the time that Mr. Pickard also explained these matters to Mr. Babcock, one of the DeForest Company's engineers, giving him directions as to how to make up commercial

holders in the factory for regular commercial use in the service of the DeForest Company. Sometime in the Summer of 1906 the factory began to put out regular holders for the carborundum detector of which Pickard Mechanical Exhibit 18 is a sample [which according to the testimony of Cloy Marshal cited above belonged to Pickard]."

In all of this, it becomes obvious that Dunwoody's





bon-steel detector with a magnet to hold the steel needle against two beveled carbon blocks under the Oscillaphone name circa 1905-6 (see Fig. 48).<sup>87</sup> Massie sold this receiver to the government and other smaller wireless companies such as the Clark Engineering Company of Detroit. Massie received two patents for the Oscillaphone, one issued on Aug. 30, 1904 (U.S. 769,005) and the other on May 8, 1906 (U.S. 819,779).

The second phase was Pickard's redesign of the carborundum detector for the American DeForest company, culminating in the introduction of this detector into their system in the summer of 1906—the first successful widespread use of crystal detector by a large wireless company. It is notable that Dunwoody's version of the carborundum detector was an abject failure, and while Dunwoody had discovered carborundum was a wave-responsive material, he had virtually nothing to do with the design that was adopted by the DeForest Company and used for many years thereafter by the successor company, United Wireless. There

are conflicting reports about whether the carborundum detector was used by the U.S. government immediately after its introduction by United Wireless. A report by the U.S. Signal Corps in the congressional record states that both the Signal Corps and the Navy had considered the carborundum detector in 1908 but rejected it because it was less sensitive than others already in use.

The third phase was the widespread adoption of the crystal detectors that Pickard himself designed and patented. It is difficult to find a book on wireless telegraphy published after 1906 that does not mention or contain a description of the perikon and pyron detectors. Other of Pickard's detectors often mentioned is the highly sensitive galena-pyrite combination and the highly stable, but less sensitive, detector made of molybdenite. Pickard, through the Wireless Specialty Apparatus Company, sold these detectors in quantity to the U.S. Signal Corps and the Navy as well as to foreign governments. All of early detectors made by the Wireless Specialty Apparatus Co. were of high quality to meet government standards,

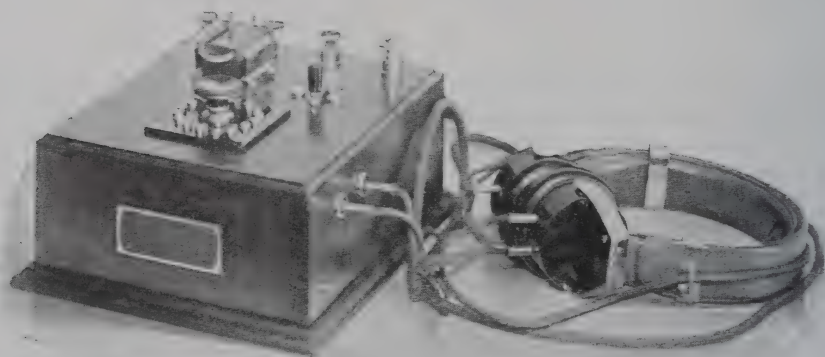


Fig. 48. The horseshoe magnet used to hold the steel needle against the carbon block electrodes can clearly be seen in this photograph of Walter Massie's Oscillaphone receiver. (W. Massie, *Wireless Telegraphy and Telephony*, 1911)

such as the as the Type 133-A detector shown in **Fig. 49** (later sold commercially in a version designated I-P-202). Pickard's patents were later licensed to other companies such as the William J. Murdock Company of Chelsea, MA, who in turn sold detectors under their own name with Pickard's patents clearly cited.

It seems very clear that Pickard was almost singularly responsible for the development and adoption of the crystal detector, and that claims by historians crediting Bose, Braun and perhaps others for the adoption of the crystal detector are unfounded. There is a clear link between Hughes' discovery of the carbon-steel crystal detector in 1879 and the introduction of the steel needle and carbon block detector by Shoemaker and Pickard. Pickard independently worked out the designs of holders to apply the correct pressure to the crystals and to make

rapid adjustments to reacquire sensitivity when necessary. He also discovered the combinations of minerals and elements that produced the most sensitive and stable detectors—although not necessarily occurring simultaneously. He participated in the creation of Wireless Specialty Apparatus specifically to develop and market his detectors, and he did so with great success for the two decades.

While Bose was the first to patent a detector with two galena electrodes, it was an impractical design that was never adopted by any wireless company. Braun developed a practical psilomelane detector, and while it was eventually adopted by Telefunken in Germany, its adoption was later than in the general adoption of the crystal detector in the U.S. and elsewhere. Dunwoody discovered carborundum was a wave-sensitive material but had no idea how

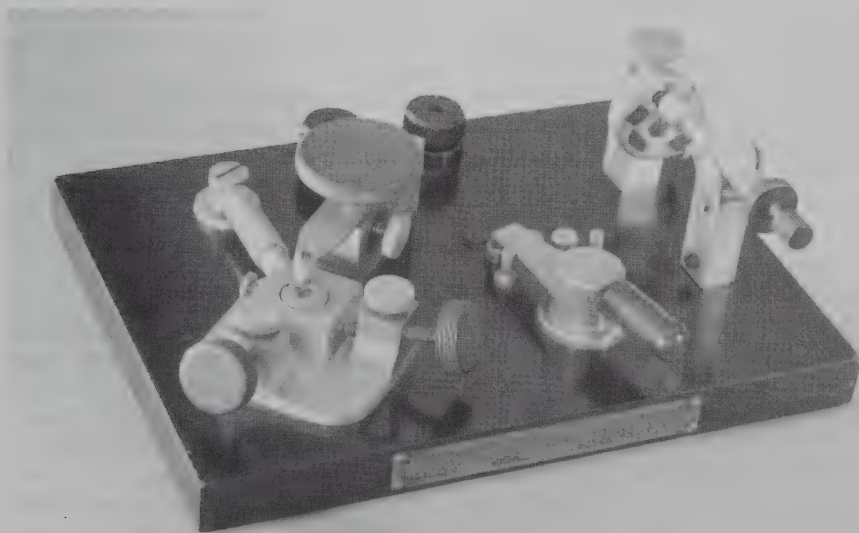


Fig. 49. The Wireless Specialty Apparatus Co. went on to manufacture and market literally hundreds of different crystal detector models, one of which was this Type 133-A crystal detector using a “micrometer adjustment” mechanism pictured in Greenleaf Pickard’s U.S. patent No. 1,118,228, and also featured in his *Electrical Experimenter* article of August 1919. (Author’s collection)



to fashion it into a useful wireless detector.

## DISCOVERY OF RECTIFICATION BY THE CRYSTAL DETECTOR

Most historians have credited Ferdinand Braun for discovering rectification in 1874, when in fact he discovered deviations from ohm's law at that time—but not rectification—as discussed in the first section. The evolution in the understanding of the principle of rectification as it applies to detection of Hertzian waves is fascinating story which has never been properly chronicled. The story begins in 1899 with the first reference to rectification of Hertzian waves utilizing an electrolytic detector, transitions to the disclosure of rectification of radio waves by the thermionic valve in 1904, and ends with a rather complete disclosure of the rectification principle by devices displaying deviations from Ohm's law—with an emphasis solid-state devices capable of detecting radio waves. The story takes place over a seven-year period involving all three states of material—liquids, gases, and solids.

The first-ever reference to detection by rectification appears to be by M. I. Pupin, which was published in several journals in 1899.<sup>88</sup> Pupin shows a sketch of an electrolytic detector, and describes how alternating current is rectified. Pupin ends his description of the rectification process with the following sentence: *"The author [Pupin] succeeded in rectifying electric oscillations of Hertzian frequency and producing electrolytic effects in them; the wire for this purpose was .025 mm in diameter."* Somewhat later, Fessenden disclosed another version of an electrolytic detector—

later designated a liquid barrater—in a patent application dated May 26, 1903 which describes a Wollasten wire dipping into a vessel containing nitric acid and a second electrode.<sup>89</sup> In this application, he disclosed an apparatus *"being capable of rectifying the alternating currents produced by the electromagnetic waves."* Shortly thereafter, W. Schlömilch disclosed his version of an electrolytic detector.<sup>90</sup>

Ambrose J. Fleming was next to recognize that radio waves could be detected using the principle of rectification, this time using the thermionic tube discovered by Edison, who applied for a patent 1883. In his book, *The Thermionic Valve*, Fleming made the following two statements:<sup>91</sup> 1) *"Edison had applied for in 1883 and obtained the [US. Patent U.S. 307,031, Electrical Indicator] for employing an incandescent lamp with a metal plate sealed into the bulb as a potential regulator for an electric light circuit, but had disclosed no application of the same with reference to the rectification of alternating currents or as a detector for electric oscillations,"* and 2) in the course of patent infringement litigation between Marconi and DeForest, the Court of Appeals stated that *"at the date of Fleming's [patent] application it was not known to men skilled in the art that a rectifier would act as a detector or that anything that would rectify oscillations of low frequency could rectify waves of the order used in radio communications..."*

Both statements were true, but at the same time, highly misleading. While Edison never disclosed an application for rectification of alternating currents, that application was disclosed by others well before prior to the filing date of

Fleming's patent—including John W. Howell in 1897, as mentioned previously. Since Fleming did not limit the claims in his patent to rectification of high frequencies, he had to file a disclaimer for the use of the Fleming valve as a low-frequency rectifier just before litigation commenced in 1916. The long delay in the filing of the disclaimer—more than tens years after the patent filing date in 1904—ultimately resulted in the invalidation of the Fleming patent in the U.S. on the technical ground that the disclaimer was not filed expeditiously, as required by U.S. patent law.<sup>92</sup>

Fleming quoted the Appeals Court correctly, but the Court's statement about men skilled in the art not knowing a rectifier would as a detector was not accurate. Pupin had disclosed rectification of radio waves by an electrolytic cell in 1899, and further, Pupin filed a patent on an electrolytic cell for the purpose of rectifying alternating currents in power lines for use in telegraph systems in 1902.<sup>93</sup> Fessenden had also disclosed that his electrolytic detector was capable of rectification.

Despite the discovery of the Fleming valve in 1904 and the general knowledge that it detected radio waves by rectification, apparently no one considered the possibility that solid state devices, generally known as self-restoring coherers at that time, operated with the principle of rectification. As late as 1906, there were two theories for the operation of self-restoring coherers, the first addressing detectors with an auxiliary battery and the second addressing detectors that operated in the absence of a battery: 1) a change in resistance caused by the electric currents which changes the current in the telephone pro-

vided by an auxiliary battery, and 2) a heating of the junction by the electric currents which in turn generates a thermo-electric current. For example, consider Pickard's explanation of how his silicon detector worked from his silicon patent U.S. 836,531 filed on August 30, 1906: "*To this end, the object is to practically utilize a combination of the phenomena of heat by electrical energy at the thermo-junction and of the generation of electrical energy by the heat energy at the thermo junction.*"

A comprehensive search of the English literature determined that no one had referred to rectification by solid state devices until George Peirce did so in his paper entitled "Crystal Rectifiers for Electric Currents and Electric Oscillations" appearing in the Physical review in July of 1907. Pierce went to great lengths in this paper to show that the carborundum detector worked by the principle of rectification. His paper was forceful, and the theory of rectification was quickly embraced by scientists and engineers including Pickard, who had been working with carborundum and clearly took note of Pierce's paper. The language appearing in Picard's detector patent U.S. 888,191 filed on Nov. 9, 1907 dropped the thermo-electric theory and embraced rectification: "*Each of the conductors A and B may be any suitable conductor of electricity, provided that at least one of them is a solid possessing the property of rectifying electrical oscillations, and the two conductors preferably have a wide difference in specific conductivity.*"

While Pierce is credited as the first to use the term "crystal rectifier," and is often credited with discovering that the crystal detec-



tor operated by the principle of rectification, it turns out that in 1906—well before Pierce's paper in 1907—Hermann Brandes published *the* seminal paper in the German literature on rectification by solid state devices with an emphasis on detection of radio waves in a paper entitled "About Deviations from Ohm's Law, Rectification Effect, and Wave Indicator of Wireless Telegraphy."<sup>94</sup> It should be noted that Pierce was aware of Brandes' work when he wrote his paper in 1907, as indicated by a footnote citing Brandes' paper. In fact, Pierce in his book *Principles of Wireless Telegraphy* published in 1910, gave credit to Brandes for laying down the principles of rectification.<sup>95</sup> This paper is of such significant historical importance, that it has been translated into English and appears here as Appendix B.

Perhaps the most fascinating part of this story is that Hermann Brandes was then a graduate student and principal assistant to none other Ferdinand Braun at the time the paper was published. It can be safely assumed that Braun was intimately involved in Brandes' work, which for the most part was theoretical, supported by some experimental results. In fact, Braun's 1906 paper summarizing his 1901 psilomelane experiments (discussed at the beginning of this paper) and Brandes paper on rectification were both published in *ETZ* at approximately the same time, and Braun referenced Brandes paper in his paper. Clearly, Braun was well aware of the rectification principle for crystalline devices, although he stopped short of using the "rectification" word in his paper. Apparently he did not want to steal any of Brandes' thunder.

It has been suggested by one

the few historians who have taken note of Braun's 1906 paper entitled "Ein neuer Wellenanzeiger (Unipolar-Detektor)"—which translates as "A New Wave Detector (Unipolar-Detector)"—that he wrote this paper simply to call attention to his earlier unpublished detector work:<sup>96</sup>

*"Presumably Braun, deeply occupied in other issues in 1906, had become aware that the crystal rectifier was receiving much favorable attention in other countries, and decided to call attention to his role in the discovery of the effect and also give an account of the research that he carried out in 1901."*

However, the evidence seems clear that Braun and Brandes had discovered the rectification effect during their experiments in late 1905 or early 1906 with the psilomelane detector described in Braun's patent, and that his 1906 paper was intended not just to summarize his earlier experimental work with psilomelane detectors, but to chronicle the fact that he and Brandes had discovered psilomelane and other solid state detectors actually operated by the principle of rectification. The title of his paper "A New Wave Detector (Unipolar Detector)" implies that the paper refers to his recently patented detector, not his experiments dating back to 1901, and the phrase "unipolar detector" implies that he knew it operated on the principle of rectification, not a thermo-electric effect. Indeed, his paper is a summary of his previous work on radio detectors, but at the same time, it signals the discovery of the rectification effect for solid-state radio detectors—if not all solid state devices.



Despite Braun's obvious involvement, the main event was Brandes and his paper in which he disclosed that solid-state devices would rectify, explained how adjusting the bias point would allow devices with both symmetrical and unsymmetrical I-V characteristic to rectify, and discovered that the rectification would be maximum when the bias point was adjusted the steepest part of the I-V characteristic, often referred to later as the "knee in the curve." The summary from his paper captures the essence of the rectification effect for solid state devices:

*"Conductor or combinations of conductors that do not follow Ohm's law can generally be used as wave indicators in wireless telegraphy because of their rectification effect."*

*"A judgment whether such device is more or less suitable for this purpose can very often be gained from its direct current characteristic [i.e., its I-V characteristic]."*

*"If such a characteristic is symmetrical in the first and third quadrant, such a device can form a wave indicator by superimposing oscillations of small amplitude on suitable dimensioned direct current."*

*"For unsymmetrical characteristics, such a device can be used as a wave indicator without auxiliary current, and its effectiveness in many cases can be increased by suitable selection of the amount of an auxiliary current that is superimposed onto the oscillations."*

While absent from Brandes'

summary, two additional findings of some importance were reported in the body of his paper:

*"The rectification effect is therefore better the smaller the radius of curvature is in the specific point and the steeper the course of the characteristic [i.e., when the operating point is at the "knee" of the characteristic curve]," and*

*"... we are not completely sure whether the characteristic remains the same for fast oscillations.... —or, said differently—whether the process that cause the deviations in Ohm's law are able to follow the fast oscillations without recognizable delay..."*

That devices which did not obey Ohm's law would detect radio waves was well-known, but it was not known that the process was rectification.<sup>97</sup> As far as this author knows, Brandes was the first to describe the rectification effect in solid state devices—and rather completely and correctly—and the first to point out that rectification was the process by which these devices detected radio waves. Apparently George Pierce must have agreed, because when he described the rectification process in his well-regarded book, *Principles of Wireless Telegraphy* published in 1910, he followed Brandes account of the rectification process, citing Brandes' paper as follows: *"In this we are following very closely the arguments laid down by H. Brandes, Elektrotechnische Zeitschrift, Vol. 27, pp. 1015-1017, 1906..."*

## CONCLUDING REMARKS

The evolution of the coherer and crystal detector as described by both participants and histori-

ans who came later are often at odds with the documentary evidence. A number of these discrepancies have been described in the historical account presented here, and are once again highlighted in the concluding remarks.

Heinrich Hertz is credited with discovering radio waves in 1888, but David Edward Hughes was actually the first to build a transmitter and receiver in 1879, and use them to generate and receive radio transmissions at distances up to 500 yards—although he did not recognize his transmissions were actually electromagnetic radiation predicted years before by Maxwell. He failed to publish his work before Hertz, resulting in one of the greatest missed opportunities in the history of electricity and magnetism. Had he published his work in 1888, radio frequencies today might be specified in terms of ‘megahughes’ rather than megahertz.

Edouard Branly is credited with discovering the coherer in 1890, a discovery which led to the development and introduction of the iron-filing coherer into telegraphic systems later in the decade, but again Hughes discovered both the iron-filing coherer and a point-contact coherer consisting of metal electrodes in 1879, well before Branly. However, Hughes discarded them in favor of several devices consisting of carbon and steel contacts because they were self-restoring, whereas the iron-filing and metal-to-metal coherers were not. Hughes’ self-restoring coherer consisting of a carbon rod resting on a steel rod with a spring to adjust the pressure was actually a crystal detector in every sense of the word. Thus, the first device used to receive radio waves was actually a crystal detector—not a coherer.

In light of the achievements of David Hughes in 1879, recent claims that Jagadis Bose was the first to discover the solid state point-contact crystal detector circa 1900 are unfounded—that honor belong to Hughes.

Sir Oliver Lodge in his 1897 “History of the Coherer” claimed to have discovered the point-contact coherer during the course of lightning experiments he performed in 1889, preceding Branly’s disclosure of his point-contact “radioconductor” by more than a year. This claim is inconsistent with the facts presented in his paper on lightning experiments which he published in 1890, and further, it is also inconsistent with an earlier note he wrote in 1893, in which he claimed that he discovered point-contact cohesion during the course of his well-known syntononic experiments—not lightning experiments as he later claimed. It is almost certain that Lodge did not independently discover either the principle of cohesion or a point-contact coherer, and at any rate, Hughes clearly discovered both the iron filing coherer and the point contact coherer long before Lodge.

Lodge is also credited as the first to recognize that Branly’s iron-filing coherer could be used as a detector of radio waves—something Branly clearly did not recognize in the first few years after his discovery of cohesion—but this also is inconsistent with the facts. Lodge stated that he was unaware of Branly’s work until reading about it in a paper about to be published by Minchin in late 1893 in which he described the similarity in the response of Branly’s iron-filing tube to the response of his impulsion cell (selenium photo-detector) when each was exposed to a spark

discharge. Minchin concluded that the effects of the spark discharge on both the Branly iron-filing tube and his impulsion cell were both due to electromagnetic radiation, and that he was able to detect this radiation at distances up to 130-140 feet. Thus, it was Minchin who actually first recognized that both his impulsion cell and the Branly iron-filing tube could be used as a detector of electromagnetic radiation—not Lodge. It was only after reading Minchin's 1893 paper that Lodge began to experiment with the coherer as a detector of electromagnetic radiation.

Lodge is credited with popularizing the coherer by giving several demonstrations using an improved version of Branly's iron-filing coherer in 1894, at which time he gave the name "coherer" to Branly's device. While, Lodge did popularize the coherer with his demonstrations, he did not actually give the name "coherer" to Branly's iron-filing device, as is generally believed. He reserved that name for the point-contact device he claimed to have discovered, which is provably documented in a table in his *Works of Hertz*. He later lamented that the press confused the issue and characterized all cohering devices as coherers—including Branly's iron-filing tube.

The coherer was replaced first by the self-restoring coherer beginning circa 1901 and later by the crystal detector circa 1906. It was first believed that the self-restoring coherer was a device with the unusual property of having a resistance which changed during the exposure to an electric pulse, immediately followed by a spontaneous return to its original resistance—in contrast to the classic coherer which requires an external measure such as a me-

chanical tap to restore its original impedance. It was soon discovered by Pickard and perhaps others that the self-restoring coherer worked in the absence of battery, and so the theory of a temporary change in conductivity was discarded and replaced by a thermoelectric theory in which currents from the electromagnetic pulses produced by heating of the junction which in turn generated a unidirectional thermo-electric current. Both theories turned out to be wrong.

In fact, all self-restoring coherers were later found to work on the principle of rectification—identical to that of the crystal detector. The major difference between the crystal detector and the self-restoring coherer was that virtually all self-restoring coherers will revert to a low-impedance state if the electromagnetic signal is too large—just like a classical coherer—thereby requiring an adjustment of the contact to regain sensitivity. Thus, the self-restoring coherer has two modes of operation, while most of the good crystal detectors do not. It was common, however, for some of the very basic crystal detectors such as the galena detector with a cat's whisker to revert to an insensitive state if over-stressed.

It is not generally known that the classical non-restoring coherer can also operate in the rectification mode. Both the non-restoring filing coherer and point-contact coherer actually have more states than the high-impedance state where it is sensitive to applied peak voltages and the insensitive low-impedance state allowing a relatively large battery current to flow. There are a number of quasi-stable states represented by non-linear I-V characteristics similar to the crystal detector,



which if accessed by adjusting the bias voltage properly, will rectify. There have been a number of instances reported of the reception of am radio stations using non-restoring coherer—not the least of which is the point contact steel-steel coherer formed by the point of a safety-pin pressed against a steel razor blade used in foxholes radios during WWII.

It is often been said that the crystal detector ultimately replaced the coherer because it was more sensitive, and while there is an element of truth to this statement, it does not explain why Hughes' steel-carbon crystal detector was not used from the outset as a detector in wireless telegraphy—after all, it had been discovered and revealed to a number of distinguished scientist and engineers in 1878-79—well before Branly's coherer was discovered in 1890 and first used in wireless telegraphy circa 1896. The reason the iron filing coherer was used first is that it was actually much more sensitive than even the best crystal detector for reception of short pulses of electromagnetic waves generated by early spark-gap sources with high decrements in use at that time. The coherer was sensitive to peak voltages as small as a few tenths of a volt, but the threshold for a crystal detector with a telephone was greater than a volt for pulse widths of 3  $\mu$ sec or less. The sensitivity of the crystal detector with a telephone increases as the square root of the pulse width for pulse widths up to about 100  $\mu$ sec. In essence, the rectifying crystal detector with a telephone can make use of the extra energy available in the longer pulse, whereas the coherer which is sensitive to peak voltage cannot.

Many historians have asserted

that the galena detector of Jagadis Bose and/or the psilomelane detector of Ferdinand Braun were the forerunners of the crystal detector used in wireless telegraphy, and that they were somehow responsible for the introduction of the crystal detector. Despite these claims to the contrary, the adoption of the crystal detector as a commercial wireless detector was almost totally due to the efforts of David Hughes and Geeenleaf Pickard. David Hughes discovered the first crystal detector in 1879, and Pickard introduced a carbon-steel crystal detector based on Hughes' discoveries into the American Wireless and Telegraph Co. in 1901, and he also used an improved steel-carbon device at AT&T to demonstrate transmission of voice by wireless (e.g. wireless telephony).

While Dunwoody did discover carborundum, his detector design was an abject failure which almost caused the demise of the American De Forest Company (which later became United Wireless), and it was Pickard who single-handedly designed the carborundum detector that was adopted by the American Deforest company, the largest wireless company in the U.S. at the time. Pickard also developed a number of detectors including silicon, perikon, pyron, galena-pyrite, and molybdenite that were adopted by the U.S. Navy and Signal Corps, foreign governments, several of wireless companies, and eventually the consumer. Pickard and his detectors were constantly mentioned in the literature of the day after 1906, but the names of Bose and Braun—and their detectors—were virtually never mentioned.

Even after the crystal detector had been adopted in 1906, still no one knew that it operated as a de-

tor by the principle of rectification. Nevertheless, even to this day, a number of historians continue to state that Braun discovered rectification in 1872. The truth is that as late as August 30, 1906 when Pickard filed his silicon patent, he and others believed that the crystal detector worked by “a combination of phenomena of the generation of heat by electrical energy at the thermo-junction and of the generation of electrical energy by the heat energy at the thermo-junction”—as Pickard described it in his silicon patent.

Other historians claimed that George Pierce was the first to recognize the crystal detector operated with the principle of rectification, as evidenced by his 1907 paper containing the phrase “Crystal Rectifier” in the title. However, it was actually Hermann Brandes, a graduate student of Ferdinand Braun, who published the first description of rectification by a solid state device in a German publication in November of 1906. Pierce was aware of the Brandes paper because it was referenced in his seminal paper published in 1907, and, indeed, Pierce gave credit to Brandes for discovering the principle of rectification by solid state detectors in his 1910 book. It is ironic that Ferdinand Braun has been credited with discovering rectification in solid state junctions 1874—which he did not do—but he and Brandes have never been properly credited with doing so in 1906, when they did!

## ENDNOTES

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This article was peer reviewed.

## ABOUT THE AUTHOR

**Eric P. Wenaas** has had a lifelong passion for antique radios beginning with his first Radiola and crystal set given to him as a young man growing up in Chicago by family friends. He experimented with radio devices and repaired radios and televisions as a hobby while in high school, and went on to study electrical engineering at Purdue University, graduating with B.S. and M.S. degrees in Electrical Engineering. He then went to the State University of New York at Buffalo where he earned a Ph.D. degree in Interdisciplinary Studies in the School of Engineering. After graduating, he moved to Southern California where he first worked at Gulf General Atomic for several years, and then moved to Jaycor, a defense company in Southern California, where he spent most of his career, first as an engineer and later as the President and Chief Executive Officer.

Upon his retirement in 2002, he set out to research the early days of wireless and document

interesting historical vignettes based on original documents of the era. He has written articles for the *AWA Review* and the *Antique Radio Classified*, and has recently published a critically acclaimed book, *Radiola: The Golden Age of RCA - 1919-1929*, covering the early history of RCA—including the formative years of the Marconi Telegraph Company of America. For this work, he received the AWA Houck Award for Documentation in 2007. He is a member of the IEEE and the Antique Wireless Association, and is a past member of the American Physical Society. Dr. Wenaas resides in Southern California and continues to enjoy collecting and displaying radios, and researching the early days of wireless.



Eric Wenaas

## COHERERS TO CRYSTAL DETECTORS - APPENDIX A

Braun, F. A New Wave Detector. (Unipolar Detector.)<sup>1</sup> Reprinted from *Elektrotechnische Zeitschrift*, Volume 52, 1906.

In the year 1874 (*Annalen der Physik*, 153, p. 556, 1874) I detected deviations from Ohm's law for a category of substances. Among those belong artificial and, above all, natural sulfur metals, such as lead glance, pyrite, copper pyrite; complex substances, such as arsenopyrite, fahlerz; additionally oxygen compounds, such as pyrolysite; but also – at least it appeared like that – uniform substances such as crystalline selenium. I finally found a particularly suitable material in psilomelane, a manganese containing mineral which can be found in large, earthy masses, and which can easily be cut and polished.

If one takes selenium aside (which probably developed selenium metals at the electrodes with the molten electrodes and the long time heating to approx. 210 °C), this class of substances could be combined as binary compounds which, however, conduct without electrolysis.

Based on further experimentations I believed to be justified that indeed pure metallic conduction was existent. This assumption has become doubtful by experimentations which were published in the course of this year. There are currently still unsolved contradictions between the results of my observations and the newer ones, and I have so far not had time to study this myself, or have it studied, for the purpose of clarification.

Independent from the interpretation are the facts to start with. These are essentially the following: By means of two metallic electrodes, such substance is integrated into an electric circuit. These electrodes consisted in different experimentations of pressed metal sticks, mostly rounded on the bottom; or of fitting formed attachment screws with broader surfaces and possibly between material and metal inlaid brush of metal foil (gold leaf, tinfoil), or of mercury boats, or of electrodes which are screwed to the material cut in plate form like joiner's clamps.

It then resulted that the resistance of the substance was generally a function of the current, and normally decreased with the current; this dependence was often different for different directions of the current, in the way that the resistances were identical or converged against the same value for small currents, but diverged for larger currents. This last behavior naturally assumed another asymmetry, and that must, as I have proven, be looked for in the vicinity of the electrodes (see *Ann. I*, p. 97, 1877).

The behavior of the named substances reminds of that of gases, and therefore the assumption could be made that layers of such, which could be supposed between the material and the electrodes, caused these phenomena. I have proven that that is not the case (see *Ann. 4*, p.476, 1878); in addition, also, that the heating of the surrounding of the electrodes is not the reason. In addition I could determine that the resistance (at least qualitatively) takes, within 1/100 second of current connection, the value valid for continuous current connection (see *Ann. 19*, p. 350, 1885), and at the occasion of other experimentations Prof. Cohn has found that it also follows oscillations of 25,000 changes per

second.

Such substances must show the following phenomena:

a) If asymmetries exist relative to the current direction, they must have the effect of a valve relative to symmetrical alternating current. One could think to suggest that photo-electric current is caused by this, which, as is known, is shown by selenium. However, the pursuit of this thought has not led me to a positive result. While currents occurred during the lighting of the electrodes, which, however, at least for the main part, could be traced back to the heating effect.

b) They must – because of the dependence of the resistance from the current – allow an unsymmetrical alternating current generally to pass also on one side. That could, indeed, be proven easily (see *Ann.* 1, p. 108, 1877).

c) For a symmetrical alternating current they can, if they are connected in a circuit with a battery, also provide the effect of a valve. Because as soon as the current is no longer proportional to the EMF but rather grows faster the EMF, an unsymmetrical current curve could result from a symmetrical applied voltage.<sup>2</sup>

The characteristics of the unipolar conducting substances suggested to me to use them for the indication of electrical oscillations.

In May 1901 I performed some tests in the laboratory and found that indeed a telephone receiver which was connected into a circuit consisting of psilomelane and other elements, provided clear and sharp sounds when small fast oscillations were fed into the circuit. The result was verified, and with surprisingly good success at that, at the stations for wireless telegraphy, which at that time work was performed at the Strassburg Forts of the Royal Prussian Airship Department under leadership of Captain von Sigsfeld.

That the resistances also follow the very fast oscillations used in this case, could, according to the knowledge at that time, not be predicted with certainty, but on the other hand also did not sound strange. It appears more like a wonder that the very fast current pulses flow with noticeable intensity through the coil of the telephone receiver which contains a large self-induction.

The experimentations then were left aside again, other than occasional repetitions; I came back to them only in December 1905, and have taken them up again together with my then-assistant Dr. Brandes<sup>3</sup>.

The laboratory observations showed that, in consistence with my earlier experience, all named substances can be used, but differently well. If one positions, for example, a polished lead glance plate on a larger metallic surface which serves as one of the poles, it appears that when probing the upper surface with a wire that the different parts behave very differently. Some areas are not effective, while other areas which are often limited to a very small region (which can also be recognized in reflected light by different mirroring) are extremely good. The best among the different materials tested proved again to be the psilomelane. It is uniform and allows the use of larger electrodes. I repeated the laboratory observations at the end of December in Berlin at the Society for Wireless Telegraphy. There the substances served directly as wave indicators in receivers. The results observed in Strassburg were confirmed, but the sensitivity was not as high as with a Schlömilch-cell. Mr. Schlömilch's continued effort resulted in removal



of this last imperfection and brought the sensitivity to the level of the electrolytic wave indicator.

Since the resistance of the psilomelane wave indicator is still very high, it would attenuate the oscillations too much if it was directly integrated in the receiver or in the resonance circuit. It is, therefore, arranged in the same way as the Schlömilch-cell: the oscillations are located in a resonance capacitor circuit; the psilomelane is connected in parallel to a part of the self-induction. The optimized conditions must be determined empirically. As is known, the attenuation of the circuit is enlarged also for this arrangement due to the Ohmic resistance connected in parallel; despite this, a satisfying selectivity can be observed.

## SUMMARY

It is reported about observations by the author in the past relative to unipolar conduction in solid substances, and about the application of such for the development of a convenient and sensitive wave indicator.

## NOTES

1 Received Oct. 24, 1906

2 If one assumes for instance that a constant  $p$  is superimposed on a periodical EMF  $\alpha \sin 2\pi \kappa t$ ; and that in addition the current  $i$  is connected to the EMF  $e$  through the relation

$$i = \lambda_1 e + \lambda_3 e^3$$

( $\lambda_1$  and  $\lambda_3$  are constants), then, during one oscillation length  $T$  the following amount of electricity will pass through:

$$(\lambda_1 p + \lambda_3 p^3 + 3/2 \lambda_3 p a^2) T;$$

That means that the medial current is increased by the oscillation by  $3/2 \lambda_3 p a^2$ .

3 Mr. Brandes has in the meantime reported about the same together with other phenomena in the "ETZ" 1906, p. 1015.



## Coherers to Crystal Rectifiers - Appendix B

**Brandes, H. About Deviations from Ohm's Law, Rectification Effect, and Wave Indicator of Wireless Telegraphy. Reprinted from *Elektrotechnische Zeitschrift*, Issue 44. Nov. 1, 1906**

1. The simplest expression for the interdependence between current and voltage in a conductor for stationary current is Ohm's law  $e = iw$ . With its help, the situation in a circuit or a portion of a circuit could generally be easily determined. An essential condition of this law is that, for a certain temperature,  $w$  is a constant, which only depends on the material consistency of the conductor and its geometrical dimensions, which otherwise, however, is completely independent of the current and the voltage or the EMF. It is common to express the fulfillment of this condition by the expression that the conductor follows Ohm's law.

The interrelationship becomes much less transparent and less accessible to mathematical analytical analysis if – like, e.g., in gases – the interdependence between current and voltage cannot be determined anymore by Ohm's law. In such case, one must rely mostly on the analysis of characteristic curves, for which we want to be understood as a graphical presentation of the form  $i = f(e)$ . This allows describing such phenomena in the simplest and most complete way, to gain an overview about the existing interrelationships, and to master them to a certain degree by means of tests.

The proof of the usefulness of such presentations, on one hand, has been demonstrated for a long time by engineering by evaluation of the processes occurring in the cylinder of a steam engine, as well as by the issues linked to self-inducing dynamo machines. That the procedure can also be rather effective in other areas of electric phenomena has been demonstrated by the works of W. Kaufmann<sup>1</sup> and the subsequent works of Th. Simon<sup>2</sup>. We, too, want to use this process further on.

2. Besides the already mentioned gases and vapors that do not follow Ohm's law, a number of bodies are known that show a similar peculiar behavior. This includes electrolytes if polarization appearances occur in them, and, additionally, particularly solid bodies evaluated by F. Braun<sup>3</sup> and others<sup>4</sup>, such as psilomelane, pyrolusite, selenium, and diverse sulfur metals. These all show a so-called unipolar conductivity under certain conditions, in other words, for them, a different current corresponds to the same absolute value of the voltage dependent upon whether the sign of the voltage is positive or negative. The following two test arrangements can generally be considered for this: one uses either unsymmetrical electrodes (plate and point), or one uses apparatuses called Holtz's funnel valve for symmetrical electrodes.

The course of the characteristic curves has a basic form shown in Fig. 4 by *B*. It is unsymmetrical in the first and the third quadrant. The unsymmetrical shape is obtained through the use of the arrangements as mentioned above; without them, the course would be in accordance with the characteristic curve *A* of Fig. 4.



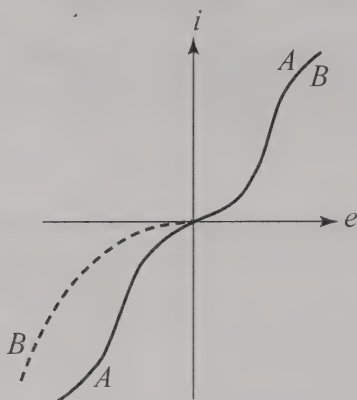


Fig. 4

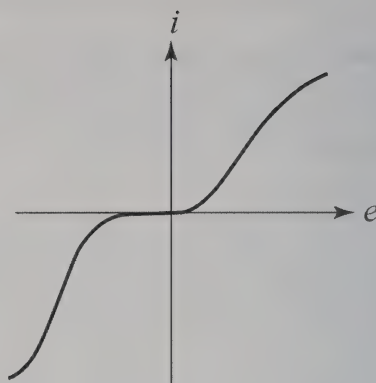


Fig. 5

If during transition from one to the other quadrant the characteristic curve coincides, for a certain length, completely or nearly completely with the axis of abscissae (Fig. 5), this type of unipolarity, for which for a certain voltage range no current is flowing in one direction, is commonly designated as "valve effect" (see W. Holtz, "Physik. Zeitschr." 1905, 6, p. 480 to 485). We shall designate from here on any type of unipolar conductivity as valve effect and distinguish the last mentioned case as "complete valve effect" as opposed to cases of "incomplete valve effect."

In regarding the characteristic curve, such as in Fig. 5, it teaches us immediately that with increasing voltage the complete valve effect can transition into an incomplete valve effect, and that, under certain circumstances, it can be zero or even change to a reverse valve effect.

If such arrangements are used in alternating current circuits, they are also designated as "rectifiers." We distinguish in this sense between complete and incomplete rectifiers, as well as note that an apparatus, which for a certain voltage amplitude is a complete rectifier, can become an incomplete rectifier at a different voltage amplitude, or can also lose its rectification characteristics altogether.

3. For symmetrical arrangements, to which a symmetrical course of the characteristic corresponds, one can achieve, in addition to the Holtz's valves<sup>5</sup>, a type of rectification effect in a different manner, which, however, is characteristically different as will be shown later. For further understandable reasons, such designs shall be designated as "electrodynamical relays" in order to indicate that this corresponds to a type of relay effect without, however, the involvement of mechanical parts.

Their design consists of the following: A direct current is sent through an arrangement of the type as explained before, with symmetrical and unsymmetrical characteristics, and superimposed by electrical oscillations. If the characteristic was initially symmetrical, it will in any case become unsymmetrical by the auxiliary current for the superimposed oscillations, if it was initially unsymmetrical; however, one can, by

controlling the auxiliary current, select in effect the most advantageous position of the unsymmetry and thus achieve the best effect. The amount of electricity flowing in one direction, defined by  $\int i dt$ , is increased as compared to the case without auxiliary current, and thus the energy is delivered by the auxiliary current source of constant voltage. This is why the designation relay was chosen.

4. In order to achieve a better insight, we tie in with a device that I have used for tests and that is shown in Fig. 6.

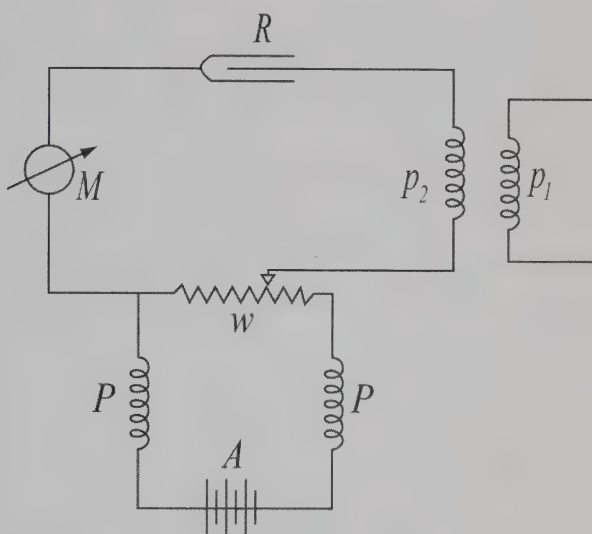


Fig. 6

Here,  $R$  indicates a vacuum tube,  $p_1, p_2$  a small transformer without iron, also for instance two induction coils,  $M$  the measurement instrument (galvanometer or telephone receiver with few coils),  $P, P$  self induction coils that shall serve for attenuating the oscillations,  $A$  several battery cells,  $w$  a tapped resistor. The resistance of the vacuum tube with Wehnelt Oxide Cathode, if one allows oneself to speak of a resistor in the spirit of Ohm's law, is located in the operational range of the characteristic at approximately 100,000 Ohms.

We assume that the superimposed oscillations have such a period that it is allowed to use the direct current characteristics for the analysis of the phenomena; in addition, their amplitude is assumed as small.

If we designate the constant auxiliary voltage as  $e_0$ , the current in  $p_1$  as  $i_1$ , and the coefficient of mutual induction between  $p_1$  and  $p_2$  as  $\rho_{12}$ , and also the total EMF in the circuit  $R, M, w, p_2$  as  $\varepsilon$ , then the following applies, if the self induction is neglected,

$$\varepsilon = e_0 - \rho_{12} \frac{di_1}{dt} \quad (1)$$

Assuming that  $\rho_{12} i_1 = f'(t)$ , therefore

$$\varepsilon - e_0 = f'(t) \quad (1a)$$

The characteristic curve around the zero point can be presented by

$$i = a\varepsilon + b\varepsilon^2 + c\varepsilon^3 \quad (2)$$

Upon selection of suitable constants, such curve shows an unsymmetrical course in the first and third quadrant. The phenomenon of saturation current that can be observed in vacuum tubes can, however, not be expressed by it.

Otherwise, it can be seen that the equation expresses Ohm's law if  $b = c = 0$ . Its graphical representation is a straight line through the zero point. If  $b = 0$ , but  $a$  and  $c$  are not equal to 0, we have a symmetrical curve in the first and the third quadrant (Fig. 4 A); if then also  $b$  is not 0, then the previous symmetrical course becomes unsymmetrical (Fig. 4 B).

From (1a) and (2) follows:

$$\begin{aligned} J &= \frac{1}{T} \int_0^T i \, dt \\ &= \left( a\varepsilon_0 + b\varepsilon_0^2 + c\varepsilon_0^3 \right) \\ &\quad - \left( a + 2b\varepsilon_0 + 3c\varepsilon_0^2 \right) \frac{1}{T} \int_0^T f'(t) \, dt \\ &\quad + \left( b + 3c\varepsilon_0^2 \right) \frac{1}{T} \int_0^T f'(t)^2 \, dt \\ &\quad - \frac{1}{T} \int_0^T f'(t)^3 \, dt \end{aligned} \quad (3)$$

We consider the following special cases:

a)  $f(t) = 0$ , i.e., only the auxiliary voltage is effective:

$$J = J_0 = \left( a\varepsilon_0 + b\varepsilon_0^2 + c\varepsilon_0^3 \right);$$

b)  $\varepsilon_0 = 0$ , i.e., only the oscillations are effective:



$$J = J_0 = -\frac{a}{T} \int_0^T f'(t) dt + \frac{b}{T} \int_0^T f'(t)^2 dt - \frac{c}{T} \int_0^T f'(t)^3 dt.$$

Therefore, the following is applicable for the general case:

$$J = J_0 + J_1 - \varepsilon_0 (2b + 3c \varepsilon_0) \frac{1}{T} \int_0^T f'(t) dt + 3c \varepsilon_0 \frac{1}{T} \int_0^T f'(t)^2 dt.$$

Now, we assume a simple, unattenuated harmonic oscillation for  $f(t)$  and also for  $f'(t)$

$$f'(t) = A \sin(\nu t + \varphi) \quad (4)$$

whereby are  $\nu = 2 \pi n$ ,  $n$  being the period number and  $\varphi$  a phase constant.

The evaluation of the integrals then delivers:

$$J_1 = \frac{b}{T} \int_0^T f'(t)^2 dt = \frac{bA^2}{2} \quad (5)$$

$$J = J_0 + J_1 + \frac{3c \varepsilon_0 A^2}{2} \quad (6)$$

The cases that appear important to us are:

I.  $b = 0$ ,  $c$  is not 0 (symmetrical characteristic):

$$J_1 = 0 \quad (5a)$$

$$J = J_0 + \frac{3c \varepsilon_0 A^2}{2} \quad (6a)$$

showing that rectification effect is only achieved with auxiliary voltage;

II.  $a$ ,  $b$ ,  $c$  unequal 0 (unsymmetrical characteristics). This is the case of equations (5) and (6), i.e., rectification effect exists even without auxiliary voltage, but it is larger with auxiliary voltage, by

$$\frac{3}{2} c \varepsilon_0 A^2$$

5. As already noted, the above considerations only apply in the vicinity of the zero point, since our Assumption 2 does not reflect the entire course of the real characteristic.

They can, however, be generalized for any points of the characteristic. To this end, we set  $i = f(\varepsilon)$ , then the following applies in the vicinity of a point  $\varepsilon = e_0$ :

$$\begin{aligned} Ai &= \frac{f'(e_0)}{1!} A \varepsilon + \frac{f''(e_0)}{2!} A \varepsilon^2 + \frac{f'''(e_0)}{3!} A \varepsilon^3 \\ &= a' A \varepsilon + b' A \varepsilon^2 + c' A \varepsilon^3. \end{aligned}$$

If we are satisfied with the first three members of the equation, and limit ourselves to the vicinity of the point that is defined by the auxiliary voltage  $e_0$  on the characteristic:

We now set

$$A \varepsilon = A \sin(\omega t + q)$$

and receive:

$$\frac{1}{T} \int_0^T A i dt = \frac{b' A^2}{2} = \frac{f''(\rho_0)}{2!} \frac{A^2}{2}.$$

If  $f''(e_0) = 0$ , i.e., we deal with an inflection point of our characteristic, or if generally  $f(\varepsilon) = \text{const.}$ , i.e., the body follows Ohm's law, no rectification exists. It should be noted that the rectification for small amplitudes is better the larger the value of the second derivation becomes at the corresponding position of the characteristic.

The radius of curvature of a curve  $i = f(\varepsilon)$  can be generally expressed as follows:

$$\rho = \pm \frac{\left\{ 1 + [f'(\varepsilon)]^2 \right\}^{\frac{3}{2}}}{f''(\varepsilon)},$$

therefore:

$$f''(\varepsilon) = \pm \frac{\left\{ 1 + [f'(\varepsilon)]^2 \right\}^{\frac{3}{2}}}{e}$$

The rectification effect is therefore better the smaller the radius of curvature is in the specific point and the steeper the course of the characteristic.

6. If we refer again to our assumption in Section 4 and set the auxiliary voltage  $e_0 = 0$  in equation (1a), then we receive from equation (2):

$$i = -a f'(t) + b f'(t)^2 - c f'(t)^3 \quad (2a)$$

Under the assumption:

$$f'(t) = \varepsilon = A \sin \nu t$$

follows:

$$i = -a A \sin \nu t + b A^2 \sin^2 \nu t - c A^3 \sin \nu t$$

or after a trigonometric conversion:

$$i = \frac{b A^2}{2} \left( a A + \frac{3}{4} c A^3 \right) \sin \nu t \\ + \frac{c A^3}{4} \sin 3\nu t - \frac{b A^2}{2} \cos 2\nu t.$$

Our approach does not consider the self-induction in the circuit and omits any delay of the causes determining the deviations from Ohm's law, so that possibly it reflects the real situation only incompletely. We recognize, however, from the above equation, that generally an applied oscillation  $\varepsilon = A \sin \nu t$  corresponds to a complex oscillation form of the current curve since the term for  $i$  includes members with a frequency higher than the basic oscillation.

7. Similar devices as those discussed above and designated as electrodynamic relays play a role as wave indicators in the wireless telegraphy, and since it was our intent to generally apply our findings to those, we were able to limit our considerations to small amplitudes of the applied oscillations.

The electrolytic cell of W. Schlömilch<sup>6</sup> has, for instance, been used for a longer time period by the Company for Wireless Telegraphy. A similar device is used by Fessenden. In the meantime, upon my request, vacuum tubes with conductive gasses or vapors have been put into operation<sup>7</sup>, and further on, the solid bodies that show deviations from Ohm's law were successfully used on the initiative by Prof. F. Braun.

In addition, the conductor in flames, analyzed by F. Braun<sup>8</sup> and others<sup>9</sup> can be used in the same way.

8. Our earlier evaluations should now be seriously expanded to the case of the attenuated oscillation

$$f'(t) = A e^{-\delta t} \sin(\nu t + \varphi)$$

However, we abstain from that initially and even more so, since we are not completely sure whether the characteristic remains the same for fast oscillations as for direct current or oscillations with a lower number of periods – or, said differently – whether the processes that cause the deviations from Ohm's law are able to follow the fast oscillations without recognizable delay, such as the cathode ray bundle the electric and magnetic forces or Kerr's double fraction the electric forces.



For the processes in the vacuum tube, it is very probable according to newer evaluations by G. C. Schmidt<sup>10</sup> that the causes for deviation from Ohm's law are able to follow the fast oscillations up to high period numbers without any noticeable delay since the polarization phenomena appear to be completely different from those in liquid electrolytes and certainly are not based on changes of electrodes.

It appears that the main reason for the deviation in question lies in the point of the unsymmetrical device, and this cause should follow faster the smaller the point electrode is selected. The transfer of sound by telephones is in any case not noticeably impacted by such electrolytic cells if one ensures with the help of a so-called differential telephone and a suitable connection of the cells that the positive and negative phases of the oscillation become effective on the membrane. Tests by me, executed in the device of Fig. 6 at a vacuum tube with Wehnelt's Oxide Cathode, with pyrolusite and psilomelane with fast oscillations, confirm qualitatively the characteristic established from direct current evaluations insofar correctly, as the most advantageous value for the auxiliary voltage derived from this characteristic can be found again upon application of the oscillations.

With our conclusion in Section 5 that the rectification effect becomes better, the smaller the curvature radius and the steeper the curve at that particular position is, coincides with the observation made by me and others that one obtains a barely recognizable change of the effect of the wave indicator upon increasing the auxiliary current in a wide range of the characteristic. With this procedure, one reaches positions of small radius of curvature, but at the same time also steeper parts of the characteristic.

9. Tests with the electrolytic wave indicator have been described by G. Ferrié<sup>11</sup>. Their result can be summarized as follows: If one positions a very fine point electrode opposed to a large platinum electrode in a saltpeter or sulfuric acid, closes the circuit by a galvanometer, and now applies to it electric oscillations from a transmittal air conductor for wireless telegraphy, one will receive an indication by the galvanometer in a certain direction. If one adds in addition an EMF and makes the point an anode, one will receive a larger indication to the other side.

I made the same observation with a vacuum tube with Wehnelt's Oxide Cathode whose cathode was not made glowing too strongly. I would mention that it was well observable how upon a certain EMF the indication of the galvanometer disappeared and then transitioned into the opposite direction.

Obviously, in both cases, when we have a rectification effect caused by unsymmetrical electrodes, we then shift, by means of the auxiliary current, the position at which we let the oscillations apply at the characteristic to an inflection point, so that it is symmetrical to both sides, and then go beyond this point again by increasing the EMF of the auxiliary current.

While we are in Fig. 7 initially at point *O*, in which we obtain rectification in one direction, we slowly go to point *A*, in which no rectification occurs, and then proceed to point *B*, at which rectification occurs in the other direction with, at the same time, amplified effect.

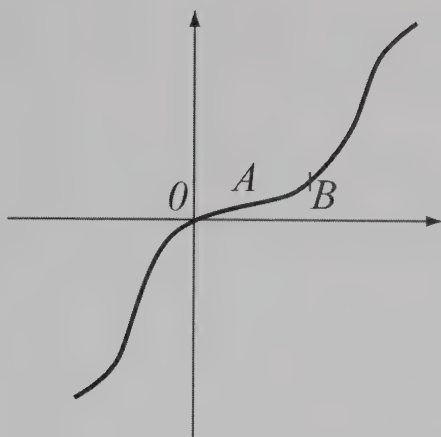


Fig. 7

Similarly occurring processes can be obtained with the Wehnelt Rectification Tube with different electrodes, without auxiliary current but rather by changing the temperature of the thread form Oxide Cathode.

The evaluation of the multiple appearances of the viewpoints developed above can be done rather easily by means of the Braun's tube, particularly when limiting oneself to low frequencies.

10. Finally, it needs to be pointed out expressly that this evaluation procedure with the help of characteristic curves can only serve as a clear description and for grouping the different effects. It only delivers the basis for theoretical analyses about the causes of these effects, and rather corresponds to a more practical need. On the other hand, it is of very large value for practical evaluations.

## SUMMARY

Conductors or combinations of conductors that do not follow Ohm's law can generally be used as wave indicators in wireless telegraphy because of their rectification effect.

A judgment whether such device is more or less suitable for this purpose very often can be gained from its direct current characteristic.

If such characteristic is symmetrical in the first and the third quadrant, such device can form a wave indicator by superimposing oscillations of small amplitude on suitably dimensioned direct current.

For unsymmetrical course of the characteristic, such device can be used as a wave indicator without auxiliary current, and its effectiveness in many cases can be increased by suitable selection of the amount of an auxiliary current that is superimposed onto the oscillations.

## NOTES

- 1 W. Kaufmann, *Ann. d. Phys.* (4) 1900, 2, p. 158.
- 2 Th. Simon. "*Physik. Zeitschr.*" 1905, 6, p. 297 to 319; "*ETZ*" 1905, p. [illegible] ff.
- 3 F. Braun, *Pogg Ann.* 1874, 153, p. 556 to 568. *Wed. Ann.* 1877, 1, p. 95 to 109; 1878, 4, p. 476 to 481; and 19, p. 310 to 352.
- 4 O. Weigel, Contribution to the knowledge of solid unipolar conductors (*Göttinger Inaug.-Diss.*), Stuttgart 1905. This work contains a good overview about research until now.
- 5 W. Holtz, *Ann. d. Phys.* (4) 1905, 18, p. 1057 to 1060; see there also older literature.
- 6 W. Schlömilch, "*ETZ*", 1903, p. 959 to 961.
- 7 The characteristics of vacuum tubes with one glowing cathode and a cold anode to be able to serve as rectifier for fast oscillations without any auxiliary voltage was indicated for the first time, to my knowledge, by J. A. Fleming (*Proc. of Roy. Soc.*.....p. 476 to 487). Later, particularly after utilization of the Wehnelt tube with oxide cathode in relay ..... by the Company of Wireless Telegraphy (October 1905), such tests can be found described also by A. Wehnelt (..... *Erlangen* 1905, 57, p. 264 to 269; *Ann. D. Phys.*, 1905,.....p. 138 to 156). His tube was used by A. Wehnelt already much earlier as rectifier for oscillations in areas of commonly used frequencies in engineering.
- 8 F. Braun, *Pogg Ann.* 1875, 151, p. 481 to 565.
- 9 H. Starke, *Verhandl. D. Phys. Ges.*..... J.E. Davidson, "*Phys. Z*" 1905, 7, p. ....112; for further literature, see these works.
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- 11 G. Ferrié, *C. R.* 1905, 121, p. 315 to 316. *Beibl.* 1905, 29, p. 1180.



## AWA Review

The Development of Radio  
in a Small Southern City

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## ABSTRACT

Two entrepreneurs, one the son of a Confederate Naval hero, the other a transplanted New England Yankee moved a small coastal city in an agricultural state from wireless telegraph to AM Broadcasting, FM and then television. This article describes the web of amateur radio operators, school radio clubs and associated radio start up businesses that made radio the economic boom field of the twenties and thirties.

Wilmington, NC, the small southern city in which I now live, is the subject of this study. The reader will first need to understand a few facts as a frame of reference. Wilmington sits on the east shore of the Cape Fear River about 20 miles upstream from the Atlantic Ocean. Today the Wilmington metropolitan statistical area holds a population of about a quarter million people; less than a quarter the size of the state's largest cities, Charlotte and Raleigh. Its economic base today is beach tourism, fiber optics, nuclear power technology, a UNC campus, a containerized ocean port facility and movie making.

Marconi introduced the wireless telegraphy communications medium to the world in 1895. Wilmington then was the economic and financial powerhouse of a largely agricultural North Carolina. In the early years of the twentieth century its port facilities on the Cape Fear River annually handled a volume of cotton exported from the U.S. second only to New Orleans. In addition to international shipping its principal business was as a railroad hub and headquarters for the Atlantic Coast Line Railroad (ACL) which ultimately morphed into today's CSX. A 1905 Wilmington Star News item headlined "Has Marconi Aboard" reported "the newest complete Marconi outfit" aboard the Standard Oil Co. steamer *Maverick* (callsign GH) docked in Wilmington. The reporter expressed awe in the shipboard operator communicating easily with a station at Hatteras (Probably station HA) from the Wilmington port area, a distance of 100 miles.

## PRIOR TO WORLD WAR I

Clarence D. Maffitt was born on his family's farm on Greenville Sound about 8 miles from the Wilmington riverfront in 1873. He was the eldest son of Confederate Navy legend, John Newland Maffitt the scourge of Union sea commerce as Captain of the privateers *FLORIDA* and *ALBEMARLE* and runner of

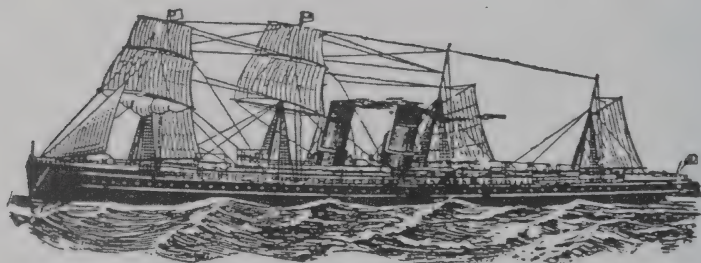
Union blockades in OWL. Today tourists visit the World War II battleship USS *North Carolina* by crossing the Cape Fear river on a water taxi named *JOHN N. MAFFITT*. Clarence also had a famous Navy uncle, Lieutenant Eugene A. Maffitt a survivor of the sinking of the ironclad CSS *ALABAMA*. Clarence had salt water in his blood.

By his middle 20's C.D., as he liked to be called, had been shipwrecked in the Bahamas, moved into the city at 520 Dock St. and had become a junior partner in a grocery and ship chandlery business on Water St. facing the Cape Fear river. At about this same time Richard A. Dunlea was growing up in an immigrant family in Taunton, MA. These two gentlemen, following different paths, would lay the foundation of wireless communication and radio broadcasting in Wilmington.

When his senior partner retired

C.D. took over and expanded the chandlery business to include the rental of small motor launches for "Boating Parties" on the river and ultimately operated a regularly scheduled steamer passenger service between several Carolinas coastal cities while also servicing the pleasure yachting community as Captain of the New York Yacht Club's *Rudder* station in Wilmington. In 1915 he was appointed agent for the North Carolina district of the Bureau of American & Foreign Shipping, better known as American Lloyds'. C.D. Maffitt continued to operate his various shipping interests until his death in 1958 at the age of 85.

A lengthy news item captioned "Important Realty Transfer" in the Wilmington Star of January 4, 1911 reported that C.D. Maffitt had purchased a three story brick building and two lots at the corner of Princess and Water Sts. Here



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Fig 1 - c1924 Ad for C.D. Maffitt & Co.

are C.D.'s comments about the purchase: see Fig. 2.

The reference to the DeForest Wireless Telegraph Co. is curious. The two successive companies that bore that name were mostly empty shells that did little more than sell worthless shares of stock. The DeForest companies were supposed to be an American challenge to the "Foreign" Marconi companies. The last company bearing the name was dissolved in 1906 and was not likely to be negotiating new wireless telegraph stations in 1911. In 1907 Dr. Lee DeForest formed the Deforest Radio Telephone Co. to promote his Audion inventions and attempted to begin broadcasting of music and speech leaving wireless telegraph behind. This effort also had little success.

Mr. Maffitt stated that he had been in communication with the DeForest Wireless Telegraph Company with a view of installing one of the latest systems of wireless on the building as soon as it is thoroughly remodelled, the same to be equipped for use to and from any part of the North and South Carolina coast, and to be used for vessels in distress, or for communicating with anyone here at any time while out of reach of telegraph, and which would be at the disposal of the entire shipping interests at this port at all times. He hopes to have this apparatus installed and working soon after October 1st, at which time he will probably remove his business to the new and handsomely fitted home.

Fig 2 - Extract of January 4, 1911 Star News Article

In 1912 the original three story building was increased to five stories with the name "Maffitts Marine Wireless Building"<sup>2</sup> in letters large enough to be seen at some distance on the river along the rooftop parapet (Fig. 3). This, the tallest structure on the riverfront was topped off with "an up to date

wireless station on the roof". The initial service appears to have included communication with the new Frying Pan Shoals Lightship which went into service in that same year. Neither of these stations shows up in the *Consolidated Radio Call Books* prior to World War I. These stations, going into operation coincident with passage of the Radio Law of 1912 but not showing up in Commerce Department publications leave open to speculation whether or not they ever actually became functional.

The post war 1919 edition of the Commerce Dept. publication is the first appearance of Maffitt's station which had then become Naval station NWN, still atop the Maffitt building, offering "General Public Correspondence" services. The lightship used callsign NLC after World War I.

C.D.'s grocery and chandlery business and association with the yachting community undoubtedly brought him into contact with one Robert G. Rankin Jr. who was also deeply involved in those same fields. Mr. Rankin was employed by various wholesale and retail grocers during this time period and served as the Purser of the Carolina Yacht Club for more than a decade beginning in 1909 and later as Commodore.

The Radio Law of 1912 instituted government licensing of amateur wireless operators and their stations. The U.S. Commerce Department published their first comprehensive listing of licensed amateur stations in July of 1913 where Mr. Rankin is identified as the holder of two station licenses. The first station, 4BB, at 3 N. 9<sup>th</sup> St. was in his home and the second, 4BF, was 10 miles east in the Carolina Yacht Club ocean side facility at Wrightsville Beach.

A *Wilmington Dispatch* article



of March 17, 1914, carries the headline "Wireless at W.H.S." and opens with: "Wilmington High School boasts of a feature in connection with its work that is not duplicated anywhere in the State, if, indeed, in the South, the same being a fully equipped and powerful wireless station, with a government licensed operator to have it in charge." That boast about not being duplicated is proven correct by the U.S. Commerce Department supplemental 1913 and 1914 lists of licensed amateur stations. The W.H.S. station 4BS was the first station licensed to a high school in the 4<sup>th</sup> district and only the third in the entire nation. The licensed operator mentioned in the article was a student, Byron B. Schonwald, 4BL. Also licensed and a W.H.S. student at this time was Marion C. Avant, 4BA. (Young Mr. Schonwald's name is spelled Schoenwald in all the Commerce Dept. lists but drops the letter E in local references. (A

precursor perhaps of anti-German sentiment at the beginning of World War I.)

Young Mr. Schonwald left Wilmington in the summer of 1914 to move to Cincinnati, OH, but was reported in another item of February 1918 as then being a Private in the U.S. Signal Corps. Marion Avant continued as an active amateur radio operator up through his graduation from high school in 1916 when he entered the local lumber business as an inspector. He unfortunately drowned while swimming off Wrightsville Beach at the age of 24.

During America's participation in World War I all amateur radio licenses were suspended and some amateur station equipment was commandeered by the U.S. Government. Commercial wireless operations continued but under careful surveillance of government agencies, primarily the U.S. Navy.

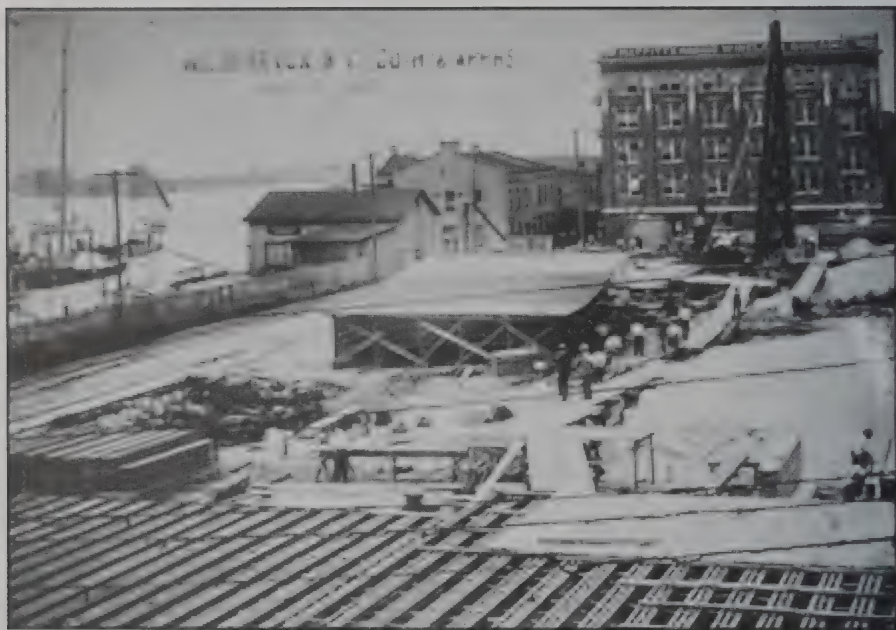


Fig 3 - Maffit's Marine Wireless Building c1916

## 1919

Amateur radio operations remained suspended for a full year after the armistice. All pre-war licenses were cancelled and new license applications were required from everyone desiring to return to the airwaves. C.D. Maffitt's various enterprises were all doing

well but his wireless station was brought under the control of the U.S. Navy as coastal station NWN handling commercial traffic with ships<sup>3</sup>. Wilmington had a new resident, 27 year old Richard A. Dunlea (Fig. 4) boarding at the YMCA and working for the Atlantic Coast Line railroad as a tele-



Fig. 4. The crew aboard the *Seminole* in Wilmington harbor, 1913. I assume that one of the crewmen was wireless operator R.A. Dunlea. Maffitt's Marine Wireless Bldg. is the five story structure to the right beyond the ship.

graph operator. Dunlea had first visited Wilmington aboard the US Coast Guard Cutter *Seminole*. Within the next decade Mr. Dunlea will become Wilmington's leading radio entrepreneur.

## AMATEUR RADIO BEFORE BROADCASTING

Before the 1917 cancellation of amateur operations Wilmington had a total of eight licensed amateur stations. Besides Mr. Rankin and the young Marion Avant the other six were as follows:

Arthur L. Humphrey, 4AF, a student at W.H.S.

Calvin Gore, 4BN, a W.H.S. student who later entered the U.S. Navy as a wireless operator.

William A. French III, 4CM, a student at W.H.S.

William C. Huggins, 4EA, probably also a student at W.H.S.

Ernest S. Bullock, 4ES, a physician and co-founder with his father of Bullock Hospital.

Belle H. Bullock, 4ES, mother of the younger Dr. Bullock.

More than half of the licensed amateur stations belonged to high school students before the war. Dr. Bullock's mother's name appears just once in the 1916 listings with the same call sign and address as the young doctor. The Wilmington High School station 4BS was no longer listed after 1914. Apparently no new license was requested after the end of the war.

Amateurs were re-licensed and returned to the air beginning in November 1919. The 1920 Commerce Department callbook listed ten stations in Wilmington out of a total of eighteen in all of North Carolina. Four of these ten had been members of the group listed

above as licensed amateurs before the war.

The 1912 licensing of amateur stations was based on an inspection of the proposed station's transmitting equipment by a U.S. Commerce Dept. Radio Inspector. The Amateur Station License described the station equipment and power level and assigned a station call sign. Amateur operator's licenses were obtained through a brief technical exam and demonstration of morse code sending and receiving skills but were a separate document from the station license. More operator's licenses were issued than station licenses. Note the two framed license documents in the upper right corner of this September 1919 *QST*<sup>4</sup> cartoon shown in Fig. 5.

The lettered captions surrounding the equipment highlight the technical improvements made through the war time enforced silent period. Most amateur operation was still by wireless telegraph signals produced by an electro-mechanical spark transmitter soon to be replaced by vacuum tube continuous wave (CW)<sup>5</sup> transmitters. Amateur use of voice modulated wireless signals, Radio Telephone, were still in the experimental stages. Note that the cartoon doesn't show a microphone.

By 1922, the year when regularly scheduled radio broadcasting became firmly established across the nation, station WBT in Charlotte, NC came on the air as the first tarheel [*native of North Carolina*] AM broadcaster with a 250 watt signal. That same year there were fourteen licensed amateurs in Wilmington, and forty-seven in the state. There were just four in Charlotte two of whom were the founders of WBT. Two more years would pass before



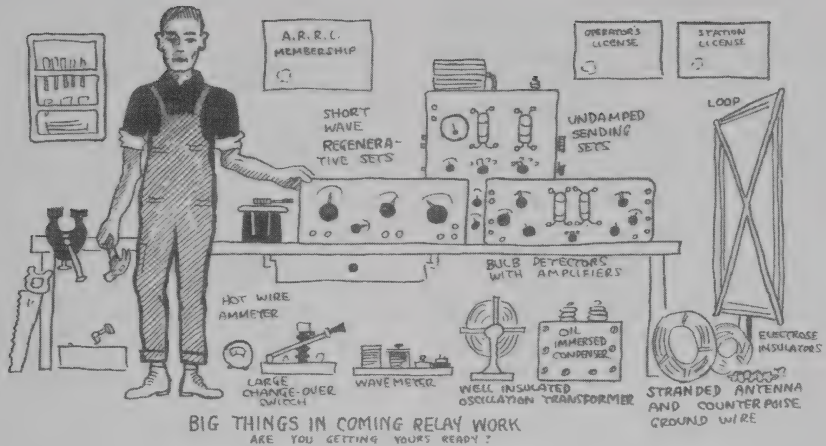


Fig 5 - Post World War I QST Cartoon

Wilmington had its own broadcast station.

## 1924 – LOCAL BROADCAST-ING ENTERS THE PICTURE

Regularly scheduled AM broadcasting spread rapidly across the U.S. in 1921 and 1922 . Before they had a hometown station of their own, many east coast newspapers regularly published program listings for KDKA, Pittsburgh, WEAN, New York and others.

Reported in the *Wilmington Morning Star* for February 20, 1924: “Local station is Ready for Operating”. A preliminary tune-up was heard the previous evening by Major Ewart W. Smith, the Secretary of the Wilmington Amateur Radio Association. WBBN was licensed by the A.B. Blake Electric Company and its station manager was Richard A. Dunlea. The first transmitter with no more than 10 watts input power was probably homemade and operated from the 5<sup>th</sup> floor of the Southern Building in the downtown business district.

WBBN was short lived. It was

replaced as reported in a *Wilmington Morning Star* front page headline of July 11, 1924: “Station WRBT Formally Opens With Pleasing Program”. The operators of WRBT were a group of Wilmington businessmen calling themselves The Wilmington Radio Association. The news item went on to describe local talents who appeared between 6:00pm and midnight the previous evening. The article stated that the station “...occupies space in the Calvary Baptist Church... and is operated in conjunction with the Wilmington Radio Association on a Wavelength of 227 Meters.” (Approx 756 KHz). The station manager of WRBT (Fig. 6) was Richard A. Dunlea.

The Stieff Studio providing the dinner concert was a local showroom for the Charles M. Stieff Co. of Baltimore, MD, a manufacturer of fine pianos with showrooms in many east coast cities of that day. Mr. Herbert Baucom (variously spelled also as Baucorn and Bausom) was pastor of a local Baptist church and the two Misses Baucom were his daugh-

ters. The Belk-Williams quartet was a group of employees of that department store, a forerunner of today's chain of Belk stores in malls throughout the Southeast. No syndicated network programming here, just down home wholesome entertainment.

Although the Wilmington Radio Association was identified by name in mid-1924 as the operator of WRBT, its existence didn't receive any overt publicity until an October 29, 1925 *Wilmington News* article describing a formal organizational meeting. The stated purpose of this group was: "...to have more pleasure in radio listening, and with this end in view, ... to locate interferences, eliminate troubles and get up a spirit of cooperation among radio owners and users." None of the named committee members appear to have ever been licensed amateurs. However the fact that the organizing meeting was held in the county courthouse with the permission of the county commissioners lent a sense of local governmental support for this group.

The next day a follow up article captioned "Wireless Association Formed Here" reported that the elected officers were: President, Raymond Hunt; Vice President, A.B. Blake; Secretary, H.H. Hunt. A restatement of the association's purpose read: "...to promote cooperation between radio users as well as betterment of service."

These officers were all prominent citizens of Wilmington. Raymond Hunt was Vice President and General Manager of the Tidewater Power and Light Co. operator among other things of the city's streetcars and the light rail line to the Wrightsville Beach resorts. A.B. Blake (A.B. is variously identified as Allen B. and

**Daily**  
**RADIO PROGRAM**

---

**TODAY'S PROGRAM**  
**WRBT**

---

213.3 Meters—1370 K. C.  
 WILMINGTON, N. C.

- 12:30-2:00—Wilmington rest hour.
- 6:30-7:30—Stieff dinner concert direct from the Stieff studio.
- 7:45—World Book Man.
- 8:00—Weston E. Britt, vocal and own accompaniment and Richard Dobson, trombone, in a thirty-minute program. Miss Jessie Beth Whitlock, piano solo.
- 8:30—Program by Miss Elizabeth Baucom, Herbert Baucom and Miss Lyda Baucom. "Dream of Love" (clarinet solo)—Herbert Baucom. "Gypsy Love Song" (viola and clarinet duet)—Elizabeth and Herbert Baucom. "To the Sea" (piano solo)—Miss Elizabeth Baucom. "Perfect Day" (viola and clarinet duet)—Miss Elizabeth and Herbert Baucom. "Lassie o' Mine" (vocal solo)—Miss Lyda Baucom, accompanied by viola and clarinet—Elizabeth and Herbert Baucom. "Smiling Thru" (viola and clarinet duet)—Miss Elizabeth and Herbert Baucom.
- 10:00—Belk-Williams male quartet.

Fig 6 - WRBT Program Listing for July 2, 1924

Allie B.) was the owner of an electrical contracting business and the original licensee of Wilmington's first station WBBN. Although the newspaper article identified the Secretary as H.H. Hunt, I believe this was actually H. Lacy Hunt Sr. the father of one of the student operators of the New Hanover High School Radio Club amateur station 4DW. (More on that high

school club later). Mr. Hunt operated a wholesale grocery business on Water St. a block away from the Maffitt Marine Wireless Building.

This meeting appeared to have been an effort to put some official weight behind the question of interference to the fledgling broadcaster from various sources which undoubtedly included amateur operators. Although it was first identified by name in mid 1924 and announced an election of officers in 1925 the Wilmington Radio Association was not formally incorporated until four years after that. The *Wilmington Morning Star* for June 27, 1929 reported: "The Wilmington Radio Association was incorporated with a capitalization of \$50,000 of which \$5,000 worth of stock is already placed with the incorporators, J.C. Williams, S.F. Garrison, H.E. Stevens and Harriss Newman. The balance of stock is to be sold to Wilmington citizens at a price of \$10.00 per share. Plans are to absorb the existing 50 watt WRBT station, move it and upgrade it to 500 watts." The 1929 Secretary-Manager of the Wilmington Radio Association was Richard A. Dunlea.

The next day appeared an article headlined "Radio Company Mails Letters to Thousands" with a sub heading of "Giant Civic Enterprise to Put Local Station on Par Gets Under Way". The letter was a solicitation for subscription to the stock in the Wilmington Radio Association at \$10.00 a share with an order blank attached. It went on to say that "...while some of the business houses of the city are willing to take fair size amounts of the stock, it is going to be necessary for every owner of a radio set...to take one or more shares...".

The Radio Act of 1912 introduced U.S. Commerce Department licensing of amateur wireless stations. Then as now, passage of an act by congress did not necessarily mean that funds were appropriated to enforce the new regulations. As for the "Interference" issue; amateurs were supposedly restricted by the 1912 act to operation on *200 Meters & Down*<sup>6</sup>, i.e. the shorter wavelengths at higher frequencies than those used by the broadcasters. These wavelengths were then considered commercially useless. C.B. DeSoto in his 1936 book on early amateur operations stated that at the dawn of AM broadcasting, nearly a decade after the 1912 imposition of amateur licensing: "The 200 meter restriction, the power restriction, even the licensing requirement, existed to a considerable extent in name only". DeSoto went on to say that: "...a considerable outlay was necessary for broadcast listening in those days<sup>7</sup>...when people experienced interference they sought redress. Politicians – local, state and national – found pressure being brought to bear...by the prominent folk of their communities". I infer that this was at least one motive for the 1924 formation of the Wilmington Radio Association.

As previously mentioned, the initial formation of this group took place at a meeting in the county courthouse held with the permission of the county commissioners in 1924. The 1929 formal incorporation named J.C. Williams, S.F. Garrison, H.E. Stevens and Harriss Newman as incorporators. With the exception of Richard A. Dunlea, still serving as Secretary-Manager, none of the original 1925 officers appear to be any longer involved.



J.C. Williams was owner/manager of the Belk-Williams Department Store in downtown Wilmington. Messers Garrison and Stevens were businessmen involved in the varied commerce of the busy seaport. Hariss Newman, an attorney, represented the district in the North Carolina State House and later in the State Senate.

On the subject of interference to broadcasting, a June 1923 *QST* article titled "Concerning Amateur Interference with Broadcast Reception" summarized a study by the U.S. Bureau of Standards of several thousand reception reports within a 400 mile radius of each of two early broadcasters, KDKA of Pittsburgh, PA and WLB in Minneapolis, MN. The conclusion was that fewer than a quarter of all reception reports experienced no interference of any kind. The most prominent source of reported interference was from other broadcast stations. Confirmed amateur interference amounted to just under 6% of cases and commercial wireless telegraph stations accounted for 2%.

From this I infer that in 1924/25 when WBBN and its successor WRBT went on the air, first with 10 and later a 50 watt signal, there was a high probability of interference from both licensed and unlicensed amateurs operating spark transmitters with questionable frequency control emitting broad and spurious signals. This would have been compounded by the presence in Wilmington as in just about every other city of its size of the most common mode of public transit at that time, streetcars operated from electrically noisy overhead lines or third rails.

By the end of 1924 there were reported to be six million radios in

use in the U.S.A. and more than two thirds of those were home made<sup>9</sup>. The pride of my personal radio collection is a crystal set built by my grandfather in about 1921 and which my mother recalls listening to with the headphones sitting in a large glass bowl on the dining room table. At the end of 1925 the production of factory made sets topped home made sets for the first time.

However the average home listener hearing what he believed to be morse code signals wouldn't differentiate between amateur or commercial signals and typically blamed "hams" for almost any interference. To address the interference problem the amateurs in many larger cities by mutual agreement observed "silent hours" desisting from operations between 7:00PM and 10:00PM local time. Naval station NWN atop the Maffitt Marine Wireless building was of course also in operation at this time and many ships sailing in and out of the port were wireless equipped. It is doubtful that NWN or the shipboard stations would have observed any silent hours in deference to home entertainment broadcasting.

The first order of business for the newly incorporated Wilmington Radio Association was the acquisition of the WRBT Calvary Baptist Church Station. The studio and transmitter were immediately moved to the top of the Wilmington Hotel building.

In October 1931 WRBT was again moved, this time to the Cape Fear Hotel where it became WRAM. Later that year the transmitter was moved to a site on the Princess Street Road, then just outside the city limits. The studios remained in the Wilmington Hotel Building. Richard A. Dunlea was directly involved over the ten

year operation of all three of these earliest stations. In 1934 WRAM went off the air and was moved lock stock and barrel to Durham, NC where it became WDNC which is still on the air today. In that year there were seventeen licensed amateurs in Wilmington.

Wilmington had no hometown AM broadcaster for a short span of time between the demise of WRAM and the start-up of WMFD in April of 1935 by none other than Richard A. Dunlea, now as station licensee as well as general manager. Once again atop the Wilmington Hotel, this station began with a 100 watt transmitter and evolved over time into "The Powerhouse of Southeastern North Carolina". Power was boosted to 250 watts in 1940 and to 1 KW in 1947 operating on 630 KHz. On April 23, 1975 in the *Hanover Sun*: R.A. Dunlea Jr. the son of the broadcast pioneer is quoted as follows – "WMFD went on the air April 21<sup>st</sup> 1935 operating between 8AM and 10AM, Noon to 1:30PM and 6PM to 10PM or earlier if they ran out of programming material".

## RADIO RELATED BUSINESS

The statistical survey cited in Note #9 of this article estimated in 1924 that the annual value of the sale of parts for repair, replacement and home construction was equal to the annual value of the sale of factory built sets at one hundred million dollars each. This figure was based on an estimated listening audience of ten million people in three million homes. Classified business headings for "Radios" and "Radio Supplies" make their first appearance in the Wilmington city directory for 1924.

## Electric Maintenance Company (EMCO)

In 1922 just one block east of the Southern Bell Central Office was the Electric Maintenance Co. (EMCO) at 215 Princess St. EMCO was started c1918 listing its business then as "Electric Repairs & Storage Batteries". The following advertisement (Fig. 7) appeared in 1922.

EMCO continued doing business primarily as an electrical contractor through the early nineteen thirties but was no longer included under radio related classified headings after 1924. This reference to Wireless Amateur Supplies in 1922 makes EMCO the earliest to enter the radio business locally.

## Radio-Electric Company

The *Wilmington Morning Star* for December 3, 1922 carried an item captioned: "Radio Concern Opens for Business Monday". This was Radio-Electric Co., the first with radio in its name as its primary business, directly across the street from EMCO. It is described as being the first full line radio store in Wilmington. The store manager was Charles F. Jones formerly of EMCO and Western Electric (See also A.B. Blake Electric Co. below). Mr. Jones was assisted by Gordon S. Smith, a recent graduate of New Hanover High School (NHHS) and operator of licensed amateur station 4BX in his home since 1920.

## A.B. Blake Electric Company

The *Wilmington Star-News* reported the following on August 10, 1919:

"J.W. Blake Electrical Co. received a state charter. The company is capitalized at \$50,000 with \$10,000 paid in by J.W. Blake, President; A.B. Blake, Vice

# ELECTRIC MAINTENANCE CO.

215 Princess St.

Phone 2191

Electric Wiring and Installations Made on Contract or  
Service Agreement

Elevator and Electric Machinery Inspection and Service at  
Reasonable Cost

Armature and Motor Windings Done Properly  
at Right Prices

## Sunbeam Mazda Lamps Wireless Amateur Specialties

WILMINGTON, N. C.

Fig 7 - 1922 Advertisement for Electric Maintenance Co. (EMCO)

President and C.F. Jones, Secretary." (NOTE: C.F. Jones was also later employed by EMCO, Western Electric Co. and Radio-Electric Co.)

In 1911 John W. Blake first appeared in Wilmington doing business as an electrical contractor. In 1914 he was still in the electrical contracting business and residing on Castle St. along with A. B. Blake and Alonzo T. Blake, both employed as electricians. These were John W.'s sons.

From 1917 through 1920 J. W. Blake Electrical Co. was located at the same street address occupied by EMCO. Mr. Blake bought the building in 1918 and sold it to EMCO when he retired in 1922. There was no indication of either A. B. or Alonzo T. Blake living or working in Wilmington in this period. (Two who went off to fight the war to end all wars?)

In 1922 A.B. was now Allie B. Blake, again an electrician, but no longer residing with John W.

(Women had just gotten the vote in 1920 and we can surmise that he may have married before that but the city directories didn't begin to list the names of wives of married men until 1928). The following brief item appeared on the front page of the *Wilmington Star* below the fold on 2/12/1922 (Fig. 8):

**NEVER'S CONNECTION**  
A. B. Blake, has severed his connection with the J. W. Blake Electrical company, he announced yesterday. Mr. Blake is in business for himself at 214 Princess street, he announces.

Fig 8 - February 12, 1922 A.B. Blake Newspaper Item

The 1924 City Directory listed A.B. Blake as an electrical contractor with general offices at 225 N. Front St. along with "Radios at 127 N. Front St. Room 516", the address of the Southern Building. In a June 1924 full page advertisement encouraging readers to patronize a long list of home town



businesses, A.B. Blake was listed as providing "Electrical and Radio Supplies".

By coincidence, in that same year the first AM broadcast station in Wilmington, WBBN, had its studios and transmitter located in Room 503 of the Southern Building just down the hall from A.B. Blake's Radios. WBBN was under the control of A.B. Blake Radio & Electric Co. with Richard A. Dunlea as Station Director.

Today A.B. Blake Electric Co. headed by Eddie Blake, the fourth generation of the Wilmington Blakes, is still in business as an electrical contractor under his family's original 1919 state license number 75-U. When I interviewed him for this article he was completely unaware of his family's involvement in bringing radio to Wilmington.

### McGrath & Company

In other related research I have found that some of the earliest radio entrepreneurs on the local level were opticians. I speculate that their background in the physics of light could have led to an interest in the physics of radio or perhaps almost anything associated with "radio" in 1925 seemed like a good money maker. See below for some other mixed product lines such as the Radio and Pet Shop. Samuel C. McGrath's business advertised the following products and services in 1926 and 1928:

PIANOS  
Ivers & Pond  
Starr  
Gulbrandsen

RADIOS  
R. G. A. Radiolas  
Atwater-Kent  
Stewart-Warner

**McGrath & Co.**

302 North Front Street  
Phone 777

PHONOGRAPHS  
Edison  
Brunswick  
Victor Victrola

Records  
Radio Accessories  
String Instruments  
Player Rolls

Fig 9 - 1920's City Directory Ad for McGrath & Co.

By the early nineteen-thirties selling, installing, building and

repairing of radios was a thriving business attracting entrepreneurs across the country. Here are a few of the more interesting Wilmington entrepreneurial efforts at making it big in radio:

### The Crosley Shoppe

902 Market St. Founded by Manley D. Williams c1929. By 1932 Mr. Williams is demoted to Salesman and the shop manager is Elmer E. Boegli Jr. This shop went out of business c1935, the middle of the depression era.

### James R. Hughes

213 Princess St. Appeared in 1930 classifieds under Radio Sets and Supplies - Retail. His address places him right next door to EMCO. He lasted just one year.

### Buck's Service Station

In 1924 Morris G. Allison operated out of his home advertising as "The Battery Man". Beginning in 1932 at three different Dock St. addresses he expanded out to "Radios and Batteries" and in 1934 dropped the batteries completely. In 1938 Mr. Allison's business name changed to Buck's Distributing Co. a wholesale distributor of electrical appliances lasting into the 1950's.

### Luke French's Radio Service

130 Market St. It first appeared in 1932 owned and operated by Llewellyn "Luke" French. Luke had held amateur station license 4SU since 1926.

He continued in the radio servicing business into the fifties, operating out of his home during the depression years and later in a 13<sup>th</sup> St. storefront across the street from New Hanover High School where Bob Hodges, W4LWS (silent key) recalled that "When I

## Radio in Wilmington

was in high school I spent a lot of lunch money at Luke's".

### **Radio Service Co.**

It was operated at 114 Princess St. for just one year c1932 by John R. Dobson, who briefly held amateur station license 4TQ in 1925. In 1932 he renamed the business as the Dobson Radio Service Co. In the middle of the depression he operated out of his Grace St. home. John R. died in 1938 but his son Richard continued the radio repair business out of their home until he was drafted during WW II.

### **Radio Service & Repair Co.**

Robert L. Holmes and Raymond L. Smith were the joint proprietors of this business beginning in 1934. They advertised:

"Radio Technicians, Expert Work, We Repair All Makes. Wallace Bldg., 27 N. 3<sup>rd</sup> St corner Princess".

They both had been employed by the Atlantic Coast Line Railroad as clerks and draftsmen previous to their radio partnership. Mr. Smith held amateur station license 4VW in 1926 and later W4VW through the forties. Their effort lasted just four years with Mr. Smith dropping out before that time to become a Salesman for Sears & Roebuck Co. He held various officer positions in the Cape Fear Amateur Radio Assn. in the thirties.

### **Wilmington Cycle Co.**

A *Wilmington Star-News* classified ad for July 3<sup>rd</sup> 1934 read as follows: "Radio tubes tested free. Phone 526, Wilmington Cycle Co., 28 S. Front" Operated by Robert J. Sneed since 1914, this company did a little bit of

everything. Mr. Sneed's business listing for 1934 included:

"Sporting Goods, Radio Sets, Supplies and Repairs, Philco Radios, Refrigerators, Bicycles".

He went out of business in 1940.

### **Radio and Pet Shop**

Operated by Christian H. Bornemann at 620 Orange St. in that same July 3<sup>rd</sup> 1934 classified ad column mentioned above advertised:

"Radios repaired. Canaries \$1.98 up, Cages \$1.48. Bird and Pet Supplies".

A very intriguing mix of radio repair and pet supplies.

### **Clyde Leonard**

One feature of the radio boom in the early days was the appearance of construction articles in newspapers and magazines attempting to explain the new art to the public. Men's magazines frequently carried full page ads for radio repair correspondence courses. The most notable of these were offered by the National Radio and De Vry Institutes. Graduates received a large diploma declaring them to be "Radiotricians". The 1936 Wilmington City Directory business classified section under "Radio Repairers" listed one Clyde Leonard at 208 1/2 Princess St. bearing the title Radiotrician. Mr. Leonard had apparently upgraded his original working skills as a typewriter repairman through a radio correspondence course and established his own repair business which flourished before WW II and included Clyde Leonard Jr. after the war years.

## Carolina Printing & Stamp Co.

In *QST*, The Radio Amateur's Journal for January 1924, appeared the following classified ad: "RUBBER STAMP with large call letters \$.50; Radiogram and Relay Radiogram blanks \$.25 per hundred, Post Card \$.60 per hundred. Send us your orders. Carolina Printing & Stamp Co., Wilmington, North Carolina".

## AMATEUR RADIO CLUBS

The U.S. Commerce Department estimated that it had issued approximately 2,000 amateur station licenses in the first year of licensing under the 1912 Radio Law. By 1924 when the New Hanover High School opened with its state of the art amateur station 4DW that figure approached 15,000 of which there were just 85 in North Carolina and 10 individual stations in Wilmington<sup>10</sup>. After Robert Rankin's two stations in 1913 the next pioneer amateurs were high school students.

## Wilmington High School Scientific Club

The previously mentioned 1913 station 4BS licensed to the Wilmington High School was authorized for operation at up to 220 watts. Marion Avant, 4BA and Byron Schonwald, 4BL operated this station through 1916 along with at least the three other contemporary youthful amateurs listed below:

*Arthur L. Humphrey*, first licensed as 4AF in 1915. He lived with his father and mother. There is no mention of any siblings. In 1920 his station callsign changed to 4AQ and in 1924 he is no longer in Wilmington.

*William C. Huggins* received station callsign 4EA in 1916 and later operated from his So. 4<sup>th</sup> St. home as 4BC up through 1922. Little else is known about this early amateur.

*William A. French III* lived in an extended family of Frenchs and held callsign 4CM as a high school student in 1916.

Amateur radio was alive and well in this early period before regularly scheduled commercial broadcasting entered the picture. The club was re-instituted in the newly opened New Hanover High School (NHHS) in 1923 with station 4DW. NHHS's library maintains an archive of yearbooks dating back to 1925. On page 39 of the 1925 *Wildcat* appears the following:

"The New Hanover Radio Club has been in existence since the opening of the new High School. The Board of Education installed a magnificent receiving and sending set, and much merriment and instruction has been secured by members. This year's officers are Charles Whaley, Raymond Smith and Arthur Peebles."

These 1925 club officers Charles Whaley and Raymond Smith held personal station callsigns 4RW and 4VW respectively. Arthur Peebles would later hold callsign W4CPT in the mid thirties.

The *Wilmington Morning Star* of April 13, 1923 reported the formation of a Wilmington Amateur Radio Association at the High School with the following officers: President, Richard A. Dunlea; Vice President, Gordon S. Smith, 4BX; Secretary: Ewart W. Smith; Treasurer: Carlisle W. Blomme.

Gordon Smith and Carlisle Blomme were both NHHS stu-



dents in 1923. However R.A. Dunlea is 31 years old, obviously not a student and has been employed as a telegrapher with the Atlantic Coast Line RR since 1918. Although Mr. Dunlea was active in this and later amateur radio groups and could have held an amateur operator's license, I have not been able to determine that he ever held an amateur station license and callsign. E.W. Smith was the Secretary and Business Manager for the Dispatch Publishing Co., Wilmington's evening newspaper. Mr. Smith doesn't appear to have held an amateur radio station license. However he was an early radio enthusiast. It appears that the Wilmington Amateur Radio Association membership consisted of both adult and student amateurs and that both may have operated the school station as inferred by the QSL card below (Fig. 10).

It is unclear whether the operator who actually made the contact confirmed by this card was Lacy Hunt or Llewellyn C. "Luke" French, holder of station callsign

4SU at that time. H. Lacy Hunt Jr. was a NHHS student but I have not been able to attribute a personal station callsign to him. His signature with the word "Opr" on the QSL card includes the callsign 4SU which belonged to Luke French, in 1924 a 21 year old adult working in his family's shoe business. A frontispiece photograph of NHHS in the 1927 yearbook faintly shows a pair of masts supporting a 6 wire cage antenna on the roof at the east end of the building.

Beginning in 1931 there are callbook entries for station W4KG assigned to J. Edgar Morris at "Market & 13<sup>th</sup> St. (P.O. address 101 N. 13<sup>th</sup> St.)" the address for NHHS. During that time Mr. Morris was a teacher there. I infer from this that Mr. Morris was the licensee/trustee of the school radio club station then using this callsign. Oddly, none of the archived yearbooks contain any pictures of any of the radio club's members or the station equipment, although the summary of many graduating students indi-

**New Hanover High School Radio Club**  
Wilmington, N. C.

---

Radio 2641 1924

Ur. CU sig. hr. 7 1924 Qso. Qso

TRANSMITTER: 15 watts ACCW, chemical rectifier, 500 volts on plates;  
Radiation, 2.5 T. C. Amps.

RECEIVER: Grebe CR-9, Western Electric Power Amplifier and Loud  
Speaker; Brandes fones.

ANTENNA: 6 wire cage, 60 ft. long, 120 ft. high. A. R. R. L.

COUNTERPOISE: 8 wires, type "T", 100 ft. long.

Remarks: Sent to me by Lacy Hunt Jr. 4SU  
from the New Hanover High School Radio Club  
73's.

Fac Qsl. H. Lacy Hunt Jr. 4SU

Fig 10 - 4DW QSL Card dated April 5, 1924<sup>8</sup>

vidual extra curricular activities does mention participation in the Radio Club during their student years.

### Cape Fear Amateur Radio Association

We can assume that this organization evolved from the 1923 Wilmington Amateur Radio Association at some point in the early nineteen-thirties when a distinction between the student and adult club activities developed. By 1934 there were 20 licensed amateur operators in Wilmington when this item appeared in the *Star News* (Fig 11) :

WRAM was the last of the first three attempts at establishing an AM commercial broadcast station in Wilmington. When it ceased operation and its equipment was moved to Durham as WDUR, the Cape Fear Amateur Radio Association leased its former transmitter site for its clubhouse and station site. W4CUA continued in operation from this site through 1937. The Central Carolina Radio Club mentioned in the clipping was a group from the Raleigh and Durham area. Unfortunately, the public library microfilm archive is missing the Sunday, July 2<sup>nd</sup> paper, which would have reported further on that expected visit.

## Amateur Radio Operators Lease Former Headquarters of WRAM

The former headquarters of WRAM on the Princess street road has been leased by the Cape Fear Amateur Radio association, who will operate it as an amateur station, W4CUA, it was learned yesterday from S. C. Sweeney, secretary of the club.

Mr. Sweeney also announced that the Central Carolina Radio club, an amateur's organization will meet at W4CUA headquarters and clubhouse on July 1. Around 125 amateur radio operators are expected to attend.

The station is licensed under the federal radio commission. The call letters were granted Thursday.

Operation of the transmitter is expected to be started next week. The station is allowed a maximum range of 1,000 watts but it will be operated on about 500. It has six wave length bands, 5, 10, 20, 40, 80 and 160 meters. It will

have both telephone and code facilities.

Mr. Sweeney said the club, through the station, will handle message free of charge to the public to any point in the United States, its possessions or foreign countries which permit messages to third parties. It is prepared to act as an emergency communication unit in co-operation with the American Red Cross, city officials and the coast guard service. The club can not accept compensation, either paid or promised, for handling messages. Plans are being made to arrange a schedule with important points in the United States for handling communications.

The club is composed of 21 members. Raymond L. Smith is president and W. L. France is vice president. It will also use the former WRAM quarters as a club house.

Fig. 11. 1934 *Star News* Item

### **Cape Fear Radio Club – 1947**

All amateur radio operation was silenced during the World War II years and many members of Cape Fear Amateur Radio Association of the thirties served in the various armed services. When amateur post war operations were allowed to resume an organization meeting was held on December 2, 1947. Among the charter members of the new Cape Fear Radio Club were several names from Wilmington's earlier radio days:

Luke French, W4BJV, licensed since 1925

Guy Pigford, W4EC, licensed since 1927

Donald Parsley, W4FT, licensed since 1923

### **WILMINGTON'S RADIO PIONEERS**

#### **William A. French III and Llewellyn (aka Luke) C. French – 1920 to Post WW II**

William A. III and Llewellyn French are brothers. They are the sons of William A. French Jr. who held various corporate offices in their grandfather's business, George R. French & Sons Co., a shoe wholesaler.

In 1917 William A. French Jr. became the president of the family shoe business. William A. French III was still a high school student as was his younger brother Llewellyn. William A. III's first call sign in 1915 was 4CM when he was 17 years old. In 1924 his call sign was changed to 4AB. Llewellyn had no station call sign in his own name through this period but both apparently operated the station under William III's call signs. Llewellyn then operated as 4SU between 1925 and 1927.

In 1935 the callbook shows his station call as W4BJV followed by a parenthetical note saying "ex 4AB, 4CM, 4SU". He is identified in the November 1947 newspaper article on the Cape Fear Amateur Radio Club also as W4BJV and was remembered in 2005 by Bob Hodges, W4LWS (silent key), as having operated his radio repair shop at that time.

In 1926 William A. III has left the Wilmington area and his 4AB call sign was reassigned. He later worked for General Electric in New York and Aero-May Co. in Ohio. His younger brother Llewellyn held station call sign 4SU with a power of 50 watts still at their 4<sup>th</sup> St. family home. He was 26 years old and employed as a traveling salesman for the family shoe business.

Luke, as he was more commonly known, held various jobs identified only as "Clerk" for a shipping agent and a hardware business while living on Nun St. with his wife Louise. In 1932 he opened Luke French's Radio Service. When I interviewed Bob Hodges in 2005 he recalled that "Luke's place was on Market at 13<sup>th</sup> St., right in front of New Hanover High School. When I was in high school I spent a lot of lunch money at Luke's. He eventually moved to a larger building one block south at 13<sup>th</sup> and Dock St."

Llewellyn "Luke" French and his brother William A. III stand as Wilmington's amateur radio link from pre-WW I spark days as high school student operators to the post WW II time period along with all the technological advancement made during those decades. Luke C. French, W4BJV, certainly deserves to be called a Wilmington Radio Pioneer.





achieving the rank of Major. He was one of those present at the formation of the Cape Fear Amateur Radio club in 1947 after the World War II period of amateur radio silence.

### Donald McR. Parsley 4FT

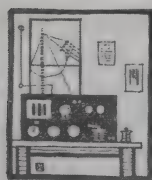
First licensed in 1922, Donald Parsley always had "the station that everybody else wished they had" according to Bob Hodges, when I interviewed him in 2005. A 1922 Wilmington news item describes the relay of a message from the Puerto Rico Radio Club to ARRL Headquarters received by Donald Parsley at his Masonboro sound station 4FT. He then relayed it across town to 4BX operated jointly by Gordon S. Smith, 4BX and Guy Pigford, 4EF at Smith's home. Smith and Pigford in turn relayed it to station 1QP in South Manchester, CT for delivery to Hartford, CT.

A return message from Hiram Percy Maxim, 1AW was relayed from 1QP to 3AQR in Hershey, PA and then through 4BX and 4FT to the Puerto Rico originator congratulating all on the establishment of two way radio relay communication between the island and mainland. Although the local news article is dated October 3, a November 1922 QST article states that these relays took place on September 16<sup>th</sup> and 21<sup>st</sup>.

Clinton B. DeSoto in his 1936 book *200 Meters & Down* briefly cites this episode as having taken place on September 15<sup>th</sup> in his chapter on Records and Achievements.

This is what amateur radio and the American Radio Relay League were all about in the early days and a couple of young Wilmington amateurs were right there establishing the foundations.

Below (Fig. 13) is a photo of



## Amateur Radio Stations



### 4FT, Wilmington, N. C.

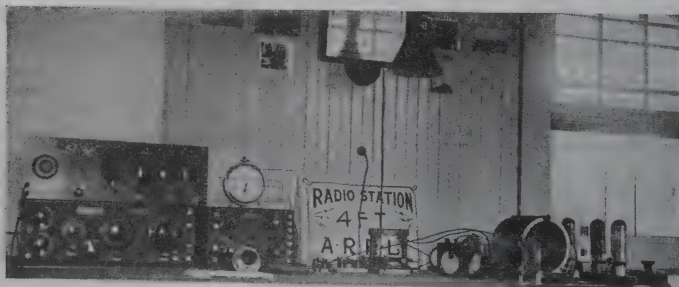


Fig 13 - January 1924 QST Feature Item on Station 4FT

station 4FT as published in *QST* of January 1924.

The station is described as "The receiver is the familiar Paragon RA-10 with its companion two-stage amplifier. Above it is a Reinartz set and two-stage amplifier. To the right of the receiver is the transmitting apparatus. Although there are sockets for four 50-watt tubes, plate power is not available to work to this capacity, hence but two tubes are generally used. Plate supply is obtained from a set of 32 volt batteries through an Esco motor-generator, a double current machine giving 1000 volts for the plates and 12 volts for the filaments of the tubes. An antenna current of five amperes is obtained when working on C.W. and four amperes on phone."

"The antenna and counterpoise attract considerable attention. There are two pipe masts made of 2<sup>1/2</sup>", 2" and 1<sup>1/2</sup>" pipe. The mast near the shack is 60 feet high while the other located 80 feet to the rear, is 70 feet high. A tapering six-wire cage is suspended between the two with a

tapering cage lead-in dropping straight down to the building. Directly under the antenna is the 35 wire counterpoise, 14 feet high. Eight posts are set equidistant on the circumference of a circle 80 feet in diameter and a No. 10 bare copper wire is run between the tops of the posts."

Attesting to the station that was envied by other hams note the string of foreign entities contacted including all 48 states and Canadian Districts. (Fig. 14)

### Richard A. Dunlea

Beginning with the 1923 formation of the Wilmington Amateur Radio Club at the High School, the name of Richard A. Dunlea appears in nearly every reference to amateur and commercial radio activities but I have found no documentation to indicate that he ever held an amateur station license. He was however one of the true pioneers of Wilmington AM broadcasting and eventually brought FM and television to the city.

His first documented appearance in Wilmington occurs in 1918

Radio <b>8BPL</b>	<b>U. S. A.</b>	Donald McR. Parsley P. O. Box 112, Wilmington, N. C.
UR <b>ew</b>	SIGNALS <del>Worked</del>	HERE ON <b>4/7/26</b> TIME <b>7:45 AM EST</b>
AUDIBILITY <b>95</b>	QSS <b>nil</b>	QRN <b>—</b> QRM <b>—</b>
<b>4 F T</b>		
Remarks <b>gld to 250 m. was using 1st + 1 step at the time.</b>		
QSO: Every state, all Canadian Districts, Holland, Chile, S. Africa, Japan, PR, Q. G, NZ, A, M, I, R, HZ, E, Y, F, G, S, H, I.		
PSE QSL	A R R L	Operator <b>TT-S</b>
CUL—OM—75%		

Fig 14 - 4FT QSL Card dated 4/7/26



when he is rooming at the YMCA and employed by the Atlantic Coast Line Railroad as a telegrapher. In 1919 he married Louise Gieschen whose family operated a local restaurant and moved in with them at their Red Cross St. home. He continued to work as a telegrapher for the railroad and for Western Union Telegraph Co. When Wilmington's first AM broadcast station WBBN went on the air in February 1924 with a 10 watt transmitter licensed to the A.B. Blake Electric Co. the station manager was Richard A. Dunlea. WBBN only existed for six months and was succeeded by 50 watt station WRBT with Dunlea still serving as station manager.

Through the entire first decade of AM broadcasting in Wilmington starting in 1924 with WBBN through WRBT and WRAM, Richard A. Dunlea was a part of the station management culminating in his own 1935 start-up of WMFD. Richard built this station into a local broadcasting powerhouse and along with his son Richard A. Jr. briefly also had WMFD-FM. They gave that up instead to pursue television as WMFD-TV which exists today as WECT-TV, Channel 6, the local NBC affiliate. Richard A. Dunlea, starting out as a telegrapher with a clear interest in the fledgling wireless technology, associated himself with the local amateur radio community, helped bring broadcasting to Wilmington and prospered from his pioneering entrepreneurial efforts.

### POSTLOG

In the first decade of the 20<sup>th</sup> century Wilmington, NC readily fit the common description of "sleepy little southern town". North Carolina was an agricultural state with cotton, tobacco

and vegetables its primary products. It had no large scale manufacturing base and no scientific or research base comparable with today's Research Triangle Park in the Raleigh, NC area. As the state's busiest Atlantic seaport wireless telegraph blossomed in Wilmington as a ship to shore communication medium promoted by businessman Clarence Maffitt. A forward thinking city school board encouraged early high school student's interests in amateur radio. The radio hobby served as a starting point for many young entrepreneurs and a railroad telegrapher named Richard Dunlea who went on to lead the introduction and growth of local radio and television broadcasting.

### NOTES:

1. *Wilmington Morning Star*, page 4, January 31, 1915.
2. Maffitt's Marine Wireless Building (MMWB), "an up to date wireless station on the roof" is from page 127 of *Wilmington: Lost But Not Forgotten* (Tetterton, Beverly: Dram Tree Books, c2005). The first references to MMWB occur in the 1915-16 city directory. In *Wilmington Through the Lens of Louis T. Moore* (Block, Susan Taylor: Lower Cape Fear Historical Society & New Hanover County Public Library c2001 ) on page 51 is a photo taken from Eagle's Island, across the Cape Fear River, of the Coast Guard Cutter Seminole (1899-1934) docked in front of the Federal building. Across Princess St. the Maffitt Marine Wireless Bldg. is clearly visible with two antenna towers distinguishable on the roof. The photo is undated but must pre-date 1934. Figure 3 is from the New Hanover County Public Library "Fales Collection" on-line photograph No. 1139 of the same section of river frontage during the 1916 construction of

the Federal Office Building clearly shows the building having five distinct floors and what appears to be a single tower near the back of the MMWB building.

3. *Wilmington Star* article of July 11, 1919 captioned "Public May Use Wireless" and "Local Radio Station Will Now Serve Commercial Interests of City" describes Naval station NWN located on the 5<sup>th</sup> floor of the Maffitt building, corner of Water and Princess Sts. under control of Fred M. Hanek "...chief electrician, radio, U.S.N.". The *Consolidated Radio Callbook* of 1919 lists station NWN at Wilmington, NC under Stations Which Handle Commercial Traffic With Ships. The first letter "N" in the callsign designates a Navy controlled station. Its listed latitude and longitude place it squarely on the riverfront in downtown Wilmington.
4. *QST* is the official journal of The American Radio Relay League (ARRL). It is a monthly magazine in continuous publication since 1914 with a break between September 1917 and June 1919 due to the war. References to *QST* throughout this article cite the month and year of publication. A complete archive of *QST* from 1914 to the present resides in the Antique Wireless Association Electronic Communication Museum library, Bloomfield, NY.
5. The cartoon reference to "Undamped Sending Sets" reflects the development of Continuous Wave or "CW" signals generated by vacuum tube oscillators. Today the term CW generally refers to morse code radio telegraphy. Spark transmitters continued to be used by some amateurs through the mid 1920's. Both Spark and CW signals were commonly heard on the air during this early period.
6. *200 Meters & Down*, Clinton B. DeSoto, American Radio Relay League 1936. Reprinted 1981. A wavelength of 200 Meters equates to about 1.66MHz near the upper end of today's AM broadcast band.
7. Factory built sets were relatively expensive. For example in my personal collection I have a Silvertone Model IV battery operated table top set advertised in the 1925 Sears Roebuck catalog for \$116.00 complete with five tubes, A and B batteries, headphones, aerial and weighing in at 135 pounds for shipping. For comparison the 1925 Model T Ford Runabout sold for \$260. The stripped down Silvertone set minus the tubes and accessories sold for \$67.00. What were then called "Light Socket" radios, i.e. those not requiring batteries or external power supplies for operation but that could be directly plugged into an AC household outlet did not become generally available until about 1927.
8. Copies of all amateur QSL cards were generously provided from the private collection of Anthony F. Ricicki, W2VRK.
9. From a reprint of "Statistical Survey of the Radio Business as of January 1, 1928" which originally appeared on pages 36 and 37 of *Radio Retailing* magazine of March 1928.
10. National amateur station populations are estimated from interpolation of various sources. North Carolina and Wilmington amateur populations are taken directly from U.S. Commerce Department Callbooks.

This article was peer-reviewed.

## ABOUT THE AUTHOR

**Allan Pellnat, KX2H** has been a ham since 1954, an AWA member for the past 25 years and is retired from both AT&T and Nortel Networks where his work began with land line Morse telegraph and culminated in satellite and terrestrial corporate computer networks. He has served as a docent in the AWA Electronic Communication Museum in Bloomfield, NY and as a regular volunteer with the Museum Annex Tuesday work crew. He serves on both the Museum and AWA Inc. boards. His interest has been on the early amateurs who were involved in the development of the radio industry. The first product of his research appeared in AWA Review Volume 18 titled *Made In Rochester. The Development of Radio in a Small Southern City* documents the extension of that study into his current hometown, Wilmington, NC.



Allan Pellnat



## AWA Review

The Gross Radio Company  
- A Historical Background

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## ABSTRACT

The 1930s were the halcyon days for the radio amateur. Nearly every red-blooded American man and boy eagerly read *QST* magazine. Aside from reading, or perhaps because of it, many of these newly minted radio bugs also sought out a company to supply their radio needs. A radio ham named Jerome Gross, also known by his call sign of 2AUD, stepped forward. In the next 20 years Jerry was to live out his own real life Horatio Alger story, through a small business located in Manhattan, in an area later to be known as "Radio Row".

The history of that business, known in its latter days as the Gross Radio Company, is recounted here. Unfortunately, time has erased much of the recorded history of Jerry Gross and Gross Radio, as it has with nearly all the equipment he produced. However, the history of Gross Radio has been reconstructed, largely via Gross's ad placements in *QST*, and other supporting references.

## RADIO BACK IN THE DAY

The time was the late 1920s, and America, like much of the world, was mired in the midst of the Great Depression. Jobs were scarce, bread lines were common, and times were admittedly hard. Yet, to borrow a phrase from Dickens, "It was the best of times, it was the worst of times", for the darkest days for our country were the beginning of the Golden Days of radio. Americans needed distractions from the cares of the day, and radio had captured the American imagination like no other invention before. One could now "listen in" on the world, bringing news from around the globe into the living room each evening.

These were the halcyon days for the radio amateur as well, with radio stores popping up in small cities and towns, offering knowledge, parts and supplies to the budding "radio bug". It was American ingenuity at its best, with whiskey shot glasses becoming insulators for the tuning capacitor, wooden breadboards and kitchen cake pans becoming the chassis for the latest receiver or transmitter creation, and tinfoil and plate glass becoming transmitting capacitors.

With funds limited, the time-honored tradition of home brewing or building your own set was the word of the day. Those who bought "commercial jobs", or assembled sets, were often looked upon with disdain, perhaps even with a tad of envy, for breaking tradition by the more experienced of the amateur community. Although fone modulation was used, CW was still the dominant mode, as it was simpler to build, therefore less expensive to the cash strapped amateur. Vacuum tubes were costly, and so most sets consisted of simple oscillators with one stage of gain. The MOPA (Master Oscillator Power Amplifier), Hartley, and TPTG (Tuned Plate Tuned Grid) rigs were the rule of the day.

## J. GROSS & CO.

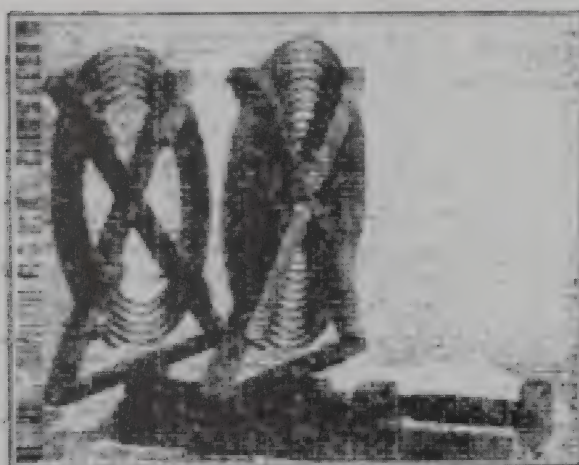
In the spring of 1925 a new radio firm, "J. Gross & Co.," entered into the mix.<sup>1</sup> It would appear that Jerry Gross 2AUD made his initial foray into the radio business in early 1925, for his first ad appeared in the March issue of the ARRL publication *QST* (see Fig. 1). The ad featured a set of "coupled inductances" selling for the sum of \$10.75, and listed the firm's address at 323 East 83<sup>rd</sup> Street in New York City. Subsequent ads in the April, September and October 1925 issues of *QST* also listed this address.

The early Gross ads were simple, at first listing only coils and miscellaneous parts, but as time went on, Jerry would become increasingly diverse in his offerings. Starting with the "coupled inductances" in 1925, and progressing to wave meters in 1926, by 1927 Gross was selling regenerative re-

ceivers, and Hartley or Tuned Plate, Tuned Grid (TPTG) transmitters, as kits or fully assembled units.<sup>2</sup>

Gross appears to have either moved or expanded its business in late 1925, for the January 1926 issue of *QST* now listed the Gross company at 907 Fox Street, with a new "laboratory" address at 74 Dey Street (Fig. 2). The June and July issue of *QST* still has the 907 Fox Street address, but the laboratory has now moved to 30 Park Place.<sup>3</sup>

In August of the same year, Fox Street was dropped, and "J. Gross & Co. Manufacturers" listed only the 30 Park Place address. With his move to Park Place, Jerry also began to offer on-air code practice using the call sign 2AUD. The frequency for this operation was listed as "39.5 meters" in his ads and the lessons were transmitted using a "Teleplex", an early



MANUFACTURED BY  
**J. GROSS & CO.**  
 Phone 323 E 83 Street  
 Lenox 10199 New York City, N.Y.

## Coupled Inductances \$10.75

Rugged  
construction  
fine screw  
adjustment  
Very heavy  
ribbon.  
Just the thing  
for short  
waves.

R.F. choke  
Coils \$1.50  
Postpaid.

Include extra  
postage for  
inductance.

Fig. 1. The first Gross ad in *QST*, March, 1925.

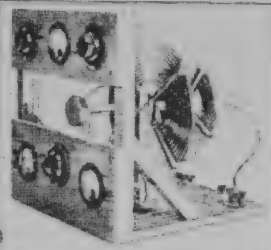
<p><b>20, 40, 80 METER</b>  <b>Low Loss Coupled Inductances</b>          PYREX } \$3.00          PILLAR }          MOUNTING } <b>EXTRA \$6.75 POSTAGE EXTRA</b>          Wound with Heavy Brass Ribbon.          Coupling Easily Varied.          This O. T. specially designed for Short          Wave Work; not daubed full of high loss          black paint, like some old-type helical          inductances.  <b>Panel Mounted Transmitters in</b>  <b>Stock 5 Watts Up</b>  <b>QUARTZ CRYSTALS, FOR CONTROLLING YOUR</b>  <b>TRANSMITTER \$6.50 EACH</b>  <b>For Personal Calls</b>  <b>Laboratory at 74 Dey St.</b></p>		<p><b>WAVE METERS</b>  <b>20 TO 200 METERS</b>  <b>\$18.75 POSTAGE EXTRA</b>          Enclosed in High Grade Case.          Lamp Indicator, Calibration          Accurate within 1% Furnished          with Galvanometer for \$33.75.  <b>DOUBLE SPACED TRANSMIT. \$5.50</b>  <b>TUNG CONDENSER 21 PLATES</b>          Best known make on the market. Stock          up on these at above price, they won't          last long.          Address Mail  <b>J. GROSS &amp; CO.</b>          907 Fox St., Bronx, N. Y. City</p>
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Fig. 2. J. Gross & Co. ad in *QST*, January, 1926.

machine that generated perfect CW characters via perforated paper tape.<sup>4</sup>

Looking at the address change and timeline, and knowing a bit about the radio business back in the late 1920s, we can speculate that like many hams, Jerry first started his business in his home, most likely the East 83<sup>rd</sup> street address, and then as the business expanded, he moved to larger commercial quarters.<sup>5</sup>

Gross continued to run monthly ads in *QST*, with an ever-expanding product line, right up until January of 1928, with the last ad of "J. Gross Company" listing its address at 30 Park Place. Jerry's last ad was for a rather simple offering, "low loss, plug in coils", a far cry from the sophisticated transmitters and receivers he had offered in earlier years. With little in the way of formal company records available, we can only guess why Jerry curtailed his advertising, but given the economic climate of the day, the country was in the grip of the Great Depression, I think it is safe to suggest that he may have encountered some sort of business reversal. This idea is further supported by the next *QST* ad to mention the name Jerome Gross, an ad sponsored by Leeds Radio.<sup>6</sup>

Whatever the cause, it appears

that Jerry went to work for Leeds Radio in October of 1929 as the supervisor of the new "Leeds Radio Lab" (Fig. 3). At the time, Leeds was best known as a purveyor of radio parts, and with the addition of Jerry to its staff Leeds began to offer kits and completely assembled radio apparatus.

The new Leeds Radio Lab advertised, "This department under the supervision of Short Wave Specialist Jerome Gross. We design, construct and advise on any material for the "Ham" Broadcasting station or laboratory. Write Jerry Gross for advice on any of your problems." Apparently this arrangement must have worked well for both parties, as subsequent Leeds ads continued to offer a line of receivers and transmitters designed and constructed under Jerry's supervision. Most of these units bore a striking similarity to the offerings of the former J. Gross Company, and it appeared that with the closing of his own business, Jerry had shifted his basic designs over to Leeds.

From October of 1929, until August of 1931, Jerry Gross was mentioned in nearly every Leeds radio ad in *QST*. However, Jerry's name was conspicuously absent in the September 1931 issue. The reason for this omission became clear just one month later.





**National Transmitting Condenser**

We carry a complete line of parts made by "NATIONAL."

# LEEDS

*The Home of RADIO*  
**45 VESEY STREET**  
NEW YORK



**General Radio Transmitting Condenser**

Type 334-P — 00025  
cap. 3000 volts  
R. M. S.  
(3500 v. peak)

\$5.50



**ELECTRAD Truvolt Wire**

Fixed Resistances from 1 ohm to 100,000 ohms — can be tapped at any resistance.

We carry a complete line of Electrad products.

**Everything in Cardwell**

Acme Thordarson Jewell  
Flechtheim Signal Bradley  
Tobe Pyrex Fleron  
**General Radio IN STOCK**



**NEON GLOW LAMPS**

Made by General Electric Co., type G-10, standard base, 100 mps., as illustrated in QST May issue page 37. Price only.....60c

Make your own transmitting and receiving coils. Copper tubing transmitting inductance.

Size of tubing		
Inside Dia.	3/16"	1/4"
1 1/8"	9c	10c
1 1/4"	9c	10c
1 1/2"	10c	11c

Prices per foot

**\$7. THORDARSON R-195 TRANSFORMER**



for H-Eliminator using the Radio Shack B-H tube. Will carry the maximum current consumption without overheating. Low 235 volts either side of centre tap — high 285 volts either side of centre. Just 50 left, after that no more at any price.

\$2.25

**By Insistent Demand**



LEEDS 90-watt socket, positive contact; heavy monomer bronze springs, heavy brass shell; will hold your tube in one position.

\$2.50

Ham green, double silk covered. No. 10 receiving inductance.

1" diameter.....30c per inch  
1 1/2" diameter.....35c per inch

Minimum shield cans and panels of every description in stock.

**NATIONAL RECTOBULB**

An unusually reliable and efficient rectifier tube.

\$10

Price each.....

**By Insistent Demand**

LEEDS 90-watt socket, positive contact; heavy monomer bronze springs, heavy brass shell; will hold your tube in one position.

\$2.50

## FEATURING

3 new items — Leeds Radio Lab. — others to follow in future issues. This department under the supervision of the Short Wave Specialist Jerome Gross. We design, construct and advise on any material for the "Ham" Broadcasting station or laboratory. Write Jerry Gross for advice on any of your problems.

**New LEEDS all aluminum plug-in Short Wave Receiver. Coils not exposed, thereby insuring 100% shielded job. Short Wave — 6-tube Receiver — detector — 2 audio, using three 201-A tubes. Universal type, continuous range 15 to 100 meters; amateur type covers Ham bands 20-40-80 meters with generous spread on the dial.**

\$37.50\*

**New LEEDS 75-watt Harley 1929 type Transmitter. Ideal for the beginner or anyone desiring a transmitter extremely simple to adjust and operate. Will operate with a 201-A tube, with 90 volts on the plate, up to a 1X-210, with 40 watts input; has plug-in transmitting coils. List price — \$55. Completely constructed \$70.**

\$57.50\*



List price \$60.  
Special offer, net.....



Special offer, completely constructed.....

Special offer, completely constructed.....

PLEASE PRINT YOUR NAME AND ADDRESS PLAINLY TO AVOID DELAY

WRITE FOR SPECIAL PRICE LIST

MAIL ORDERS FILLED SAME DAY  
10% Must Accompany All Orders

Fig. 3. Leeds Radio ad in QST, October, 1929.

In October of 1931, a new ad debuted in the pages of *QST*, heralding a new radio firm, the "Gross Radio Company" (Fig. 4).<sup>7</sup> Jerry

Gross, now W2AAE, was back in business. The new *QST* ad opened with the pronouncement that amateurs should "Work 30,000

hams and tell them that Jerry Gross has opened his own ham radio store." The new Gross Radio Company store, also known as "Jerry's Place", was originally located at 25 Warren Street, and later moved to 51 Vesey Street, an interesting address, for Leeds was also located on Vesey, right down the street from the new Gross store, in the area that later came to be known as "Radio Row".

## THE NEW GROSS RADIO COMPANY

During the 1930s Gross Radio thrived, and their ads could be found in a number of radio publications, including *QST* and *Short Wave Craft*, offering a variety of kits and assembled units. In fact, the monthly *QST* ads from Gross were often  $\frac{3}{4}$  or even full page, on the level of much larger companies like National and Leeds. The first product offered by the new company was the "Sensa-

tional S.W. Receiver", assembled and tested, for the sum of \$22. The set, a simple three tube regen, employing a type 236 as the RF amp, another 236 for the detector, and a 238 for the audio amp, was later to be named the Gross "Hawk" in an ad appearing in the March 1932 *QST* issue.

As these were the days of the Great Depression, many amateurs lacked the funds to buy even a radio kit, much less an assembled unit. So, aside from Gross transmitters and receivers, the company also sold radio parts and products manufactured by other firms. In one Gross *QST* ad, the header began "If We Don't Carry It In Stock, We'll Get It For You." Gross also offered custom building for the discerning client; proudly advertising "Our lab is equipped to build anything to your own specifications." If that were not enough, a Wednesday evening "Code Class" was even offered in the store from 6:30 to 7:30PM,



## JERRY GROSS HAS HIS OWN HAM RADIO STORE

(W2AAE)

TELL THEM—asan introductory offer, Jerry is going to give away FREE a 50 watt, crystal controlled transmitter (\$350.00 value). Every purchase of \$1 or more entitles you to a chance to win this fine job. This transmitter is an example of the fine work Jerry is doing in his completely equipped ham lab.

FREE ADVICE on radio problems Stop worrying about that temperamental transmitter—tell Jerry the symptoms and you'll be back on the air—better than ever! Your letter will receive the personal attention of Jerry Gross.

FREE—Mounting holes on copper tubing drilled free. Yes, we have bright finish tubing.

SPECIAL TRANSMITTERS AND RECEIVERS CONSTRUCTED—any type job built to your own specifications.

FREE CODE CLASS. Here is an opportunity to learn the code or speed up. The class is supervised by one of the leading commercial ops—write or call for dope.

25 WARREN STREET

COMPLETE LINE OF STANDARD AND "HARD TO GET" PARTS



NEW LINE of crystal control transmitters IN UNIT FORM. Component units of this transmitter may be purchased separately. Write for more details.

NEW YORK CITY

Fig. 4. Gross Radio Company ad in *QST*, October, 1931.

with the advice to “bring your own phones.”

Perhaps because of his parts sales business, Jerry was surprisingly tolerant of window shoppers and tire kickers, and “Jerry’s Place”, as the store came to be known, grew to become quite the gathering place for hams. Bill Orr W6SAI, writing in the February 1977 issue of *CQ* magazine,<sup>8</sup> had this to say about his visits to Gross Radio as a young ham: “Most amateurs spent their time in Jerry’s store examining the model transmitter carefully set atop a counter, and copying its circuit so they could build the equipment out of scrap parts salvaged from a defunct broadcast receiver!”

Gross Radio, like many other radio businesses of the day, offered their product in both kit, and, for an additional charge, in assembled form. Although Gross’s most famous and longest running product was arguably the CW-25 series of transmitters, the company also offered a line of receivers, antenna meters, and even a station monitor.

### EARLY GROSS TRANSMITTERS

The original J. Gross & Co., at the 30 Park Place address, appears to have offered their first transmitter in the pages of the May 1927 issue of *QST*. Details are sparse, but listed are a 7 ½ watt unit for \$47.50 and 75 watt variant “for use with the new UX-852 short wave tube”, listed for the sum of \$65.00. The set was offered as a Tuned Plate, Tuned Grid (TPTG) design. Both transmitters were offered as kits, and construction was typical of the day, a flat black panel, perhaps bakelite, with three meters arranged in a row near the top of the panel, and a series of three knobs below.

During Jerry’s time at Leeds Radio, his offerings appeared to have been limited almost exclusively to a small regenerative receiver set, and Hartley transmitter. The receiver, which covered 15 - 100 meters with three plug-in coils, offered band spread for fine-tuning, used three of the 201A tubes, and sold for \$37.50. The 7 ½ watt Hartley transmitter initially sold for \$57.50 assembled, and is shown housed in an attractive black enclosure with two front panel meters, and is noted to operate with a 201A or UX-210 tube. Precious few details about Jerry’s other designs or offerings can be found, and aside from the Leeds ads, we almost lose track of him until he resurfaces in late 1931.

In 1931, one of the first transmitters listed by the new Gross Radio Company was a 75-watt Hartley, first offered in the November issue of *QST*. The unit sold for the then princely sum of \$52.50 as a kit, or \$65 assembled and tested. Gross did not seem to skimp on the quality of parts used in his offerings. In the ad for the Hartley mentioned above, he boasted that the transmitters were equipped with “Jewell meters, Cardwell condensers, and Ward Leonard leaks” all of which were top-notch manufacturers at that time. Gross even offered the Hartley in a QRP version, advertising the “7 ½ watt” model at \$32.50 as a kit, or \$40 assembled. The optional 2000-volt, 200 milliamp power supply would set the buyer back an additional \$67.50.

In addition to the Hartley, Gross also sold a line of simple crystal-controlled transmitters. These used the type 210 tube, with an optional amplifier stage, also using a 210, boosting the power



# Startling low prices for Sterling Equipment!!



Now a greater value than ever—HOYT METERS—GERMAN SILVER DIALS—BAKELITE INDICATOR KNOBS and other refinements at no increase in price.

Your choice of 210 oscillator 210 buffer 210 amplifier or Pentode oscillator 210 buffer 210 amplifier. Can also be supplied with two 210's in push pull in output stage. Completely assembled ready for you to wire with three Hoyt meters, \$29.50, with three Weston meters, \$42.50; 210's push pull in output stage \$3.00 extra.

**CLASS "B" MODULATION UNITS**—for modulating the GC-30 complete kit, \$29.50

**RELAY RACKS**—line for mounting the GC-30 or GC-100 and all power packs. Black crystallized finish, price, \$12.50

**GC-100**—Same construction as GC-30—a new higher powered job for use with 203-A or 211 in the output stage. Completely assembled, \$39.50

## MONITOR USES FULL SIZE DRY CELLS



A real advantage for continuous monitoring. This Jerry must say this is SOME job. Has back of hand vernier dial shielded. In black crystallized finish cabinet with hinged cover complete with three plug-in coils for 20, 40 and 80 meters, all batteries and tube, wired and tested, \$9.95

**FIVE METER RECEIVER**—A REAL receiver, built in same cabinet as the Eagle, with two German Silver dial plates and fine action vernier dial. The quality of this set is above any offered—Jerry invites comparison. Has made construction—a fine job. Uses 2-237's and 1-238 tube. Employs QST super regenerative circuit. Completely assembled, \$12.50

Completely wired and tested, \$16.50

**FIVE METER TRANSMITTER**—Matched in appearance with the receiver, slightly longer cabinet supplied with two Hoyt milliammeters—Heland modulation—employs 2-245's and 2-247's—can also be used with 210's as oscillators and 250's as modulators by using one external stage of audio. Completely assembled, \$17.50

Completely wired and tested, \$22.50



**HOYT ANTENNA METERS!!**

Hot wire antenna meters 1 1/2, 3 and 5 ampere ranges. Why do without antenna meters when you can buy them at Jerry's who knows what the "Ham" wants? Special low price, \$2.95 each

Most perfectly damped meters at a price. These are not to be confused with the usual meter "harshes" 2" mounting hole, range 2 1/2" diameter, supplied in receiver.

100 m.a., 130 m.a., 250 m.a., 300 m.a., 4 volt A.C., 10 volt A.C., 15 volt A.C., 10 volt D.C. Price each, \$1.60

three for, \$4.50

## COMPLETE STOCK OF NATIONAL—HAMMARLUND—CARDWELL—JEWELL—WESTON and other standard lines always in stock—write for prices

PRICES CUT			
Plated copper tubing inductances wound and ends fitted free			
Inside dia.	3/16"	1/4"	3/16"
1 1/4"	5c turn	5c turn	10c turn
2 1/4"	6c turn	6c turn	10c turn
3 1/4"	10c turn	10c turn	12c turn

ACME SOLID ENAMELED COPPER ANTENNA WIRE	
No. 14 (any length) per 100 ft.	\$ .30
No. 12 (any length) per 100 ft.	\$ .45
No. 10 (any length) per 100 ft.	\$ .80
No. 8 (any length) per 100 ft.	\$1.20

ALUMINUM Cut to size specified	
1/16" thick per sq. inch.	7/10c
3/32" thick per sq. inch.	3/4c
1/8" thick per sq. inch.	1c
Beautiful plug-in crystal holders.	\$1.15 (limited quantity)

High grade filament transformers shielded in metal cases, center tapped secondaries 2.5 volt 10 amperes for 866's	
10 to 12 volts at 8 amperes—either type	\$2.50
Special—10 to 12 volt 7.5 amp. filament transformer extra special.	\$9.95

Billy superior crystals exclusive in New York with Jerry's—40, 80 or 160 meter guaranteed crystals.	
They must be good—otherwise Jerry would not sell them.	\$5.50
Billy plug-in moulded bakelite crystal holders, polished chromium electrodes	\$1.50

No. 10 stranded Tinned Antenna wire strong and extremely flexible only \$.85 per 100 ft. (Any length.)	
Nat-Aid S.W. coils 20-200 meters, set of four.	\$1.15
Glazed beehive stand off insulators.	\$ .67
Guaranteed 210 tubes.	\$1.40
DeForest 450 tubes, spec.	\$1.95

20% deposit with all C. O. D. orders. Include Postage.

A COMPLETE LINE OF STANDARD AND "HARD TO GET" PARTS

# "JERRY'S PLACE"

25 WARREN STREET, N. Y. C. TELEPHONE BARCLAY 7-6696



96

Sanokaa että näitte sen QST:ssä. Se on teidän tuntoimerkinne ja se auttaa QST.

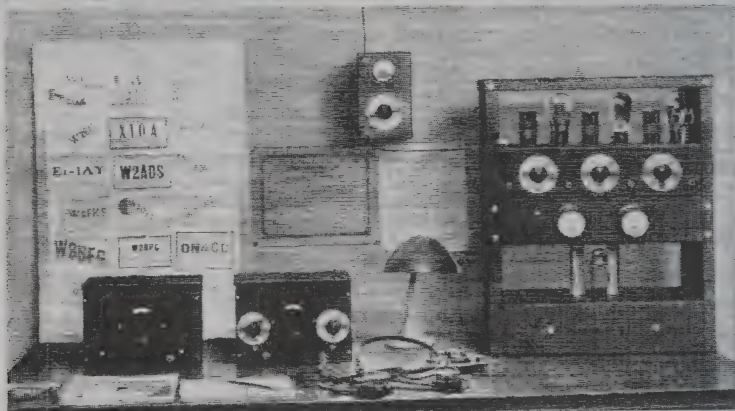
RUMFORD PRESS  
CONCORD, N. H.

Fig. 5. Ad for "Jerry's Place" in QST, January, 1933.

output up to 75 watts. These were sold as separate units, costing \$23.50 for the oscillator kit, \$23.50 for the buffer/doubler

stage, and \$57.50 for the 75-watt output amplifier section. The design was rather simple, a rectangular box, with meter and Na-

## THE NEW GROSS 25-30 WATT STATION

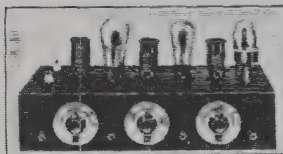


A STATION YOU WILL BE PROUD TO OWN

### Complete GROSS Crystal Control Station

CW-25 Transmitter Kit.....	\$13.50
Power Supply Kit.....	8.75
Panel Rack and Meter Panel.....	8.00
Two Moving Coil Surface Type Milliammeters.....	7.00
Eagle S.W. Receiver.....	11.95
X cut 80 or 160-meter Crystal.....	2.75
Hoyt Hot Wire Antenna Meter.....	2.95
Antenna Tuning Condenser.....	1.25

### The GROSS "CW-25" Crystal Control Transmitter Kit . . . \$13.95



The "CW-25" transmitter kit due to its low cost makes it possible for anyone to own a modern crystal controlled station. A schematic hook-up and parts layout sheet as well as tuning instructions are furnished, thus enabling the most inexperienced operator to wire and put the set on the air, for real results. The "CW-25" is supplied with a shrivel finished sturdy metal chassis under which all parts are mounted, making the wiring and components dustproof. A plug-in crystal holder is furnished with the kit. Only one milliammeter is required for tuning the transmitter and each stage is provided with a jack for this purpose. The "CW-25" uses one '47 as crystal oscillator, one '46 as buffer or

doubler and two '46's in the amplifier stage. One set of three coils is supplied with the kit for 20, 40, 80 or 160 meter band. Any additional coils are 75 cents each.

### The GROSS "CW-25" Power Supply Kit . . . . . \$8.75

Mounted on shrivel finished metal chassis which matches the "CW-25" transmitter. Heavy duty power transformer, chokes, condensers, bleeder, etc. supplied. Uses one '83 rectifier. This unit and the transmitter make a neat combination as well as an efficient one.

### The "EAGLE" Three-Tube Short Wave Receiver

"Band Spread" over any portion of the tuning range — only finest material used thruout. Employs one '32 R.F., one '32 detector and one '33 Pentode Audio — 15 to 200 meters — four coils supplied. The "EAGLE" is economical — two dry cells will operate the filaments. See March or April QST for full description of this most excellent value in short wave receivers.

"Eagle" completely wired and tested. . . . . \$11.95      Three tubes tested in your receiver. . . . . \$3.00

### GROSS Band Spread Monitor . . . . . \$9.95

Completely wired and tested, with full size dry cells, 22.5V. C battery and type '30 tube

**GROSS RADIO, INC.      51 VESEY STREET      NEW YORK CITY**

6

Say You Saw It in QST — It Identifies You and Helps QST

Fig. 6. Gross Radio, Inc. ad in QST, February, 1934.

tional Radio Type "B" vernier dials on the front panel of each unit. Band coverage was advertised as 80, 40 or 20 meters via the plug-

in coil sets. These rigs were to be offered only for a short time, and were later combined into one cabinet, the Gross "GC-30" set.

In the GC-30 set, the oscillator, buffer/doubler and output stage were all built into one enclosure, each section was divided by a metal partition, and individually metered. Plug-in coils covering 80, 40 and 20 meters were used in each stage for band selection. The GC-30 (I'm assuming the "GC" stood for "Gross Company") used the same 210 tube lineup as the early crystal controlled sets, but also offered an optional type 245 in the oscillator, if the customer so desired. In keeping with a theme he used throughout the life of his company, that of offering a "foundation kit" with options, Jerry also offered two different types of meters; the Readrite was standard, and the Weston optional. The base cost of the set with three Readrite meters, and three plug-in coils, was \$29.50. The upgraded model using the Weston meters was given as a shocking \$42.50!

The GC-30 was soon joined by the "GC-45" and "GC-100" transmitters, which were priced at \$37.50 and \$39.50 respectively. The "GC-45-B" modulator and power supply were offered as options for an additional cost. The GC-45 used the type 47 for the crystal oscillator, a type 210 in the buffer, and single 210 in the push-pull amplifier. The GC-100 tube lineup was the same, with a pair of type 210s replacing the single 210 in the final amplifier. The new GC-45-B unit offered both the power supply and a class B modulator on the same chassis, for the sum of \$52. Type 57 and 59 tubes were used in the first two stages of audio, with a pair of 59s used as the output on the modulator deck. Gross listed the audio output power at 30 watts, and claimed that the GC-45-B would "fully modulate a 40 watt carrier."

Hoyt meters were standard, with the Weston meter option also offered with these sets, for the additional cost of "\$3.50 per meter."

## GROSS RECEIVERS

The Gross receivers took their names from the avian kingdom, with names like the "Hawk", advertised at "\$22 net", and the "Eagle" an entry level three tube regen, comparable to the National SW-3, for \$16.95. A low cost version of the Hawk, known as the "Hawk Jr.", without the RF stage, was also offered for a short time at \$14.75.

The Hawk series lasted only a short time. First introduced as the Gross "S.W. Receiver" in January of 1932, the Hawk appears to have been dropped from advertisements less than a year later, last appearing in the October 1933 *QST*. The tube lineup stayed constant throughout production, using the type 236 as the RF amp, another 236 for the detector, and a 238 for the audio amp. Gross proudly offered low-loss coil forms in the Hawk, using the new Hammarlund Isolantite material. The Hawk required three coils for operation, one for each stage in the set, and Gross advertised the coverage "from 17.5 to 110 meters." Additional coil forms, for those who preferred to wind their own, could be purchased for 58 cents.

The "Eagle", first introduced in the December 1932 *QST*, was positioned as a low cost option to the Hawk. Like the Hawk, it also used three tubes, type 232 for the RF and detector circuits, and a type 233 for the audio. The unit was small for the day, with the metal cabinet measuring 6" x 7" x 9 1/2", and was advertised by Gross as being suitable for "portable use". Like the Hawk, band coverage was



**The Gross "EAGLE"—a new sensational 3-tube  
S. W. Receiver**

**\$11.95**

*The only popular priced set having  
the band spreading feature*

**CHECK THESE FEATURES!**

**SCREEN GRID 232 R. F.** and screen detector offering highest possible gain and most efficient regeneration.

**PENTODE POWER AUDIO—233** gives more gain than obtained from two ordinary transformer coupled stages. Will operate speaker on most stations.

**TANK CONDENSER**—is operated from the front of panel and eliminates the objectionable necessity of lifting the cover. Speedy range changes at your finger tips. The **ADDITIONAL** condenser employed here gives much finer tuning than is possible with the ordinary large condenser.

**BAND SPREADING CONDENSER**—very small capacity permits widest calibration spread over a multitude of ranges. This feature gives you really two receivers for the price of one.

**DIAL**—Latest design, real vernier control over any position of the frequencies covered. Absolutely will not jump or slip—very rugged.

**REGENERATION CONTROL**—Employs condenser for stability, ruggedness and velvet-like smoothness, not noisy like resistances.

**POWER CABLE**—Eliminates possibility of wrong connections and insures absolute electrical contact.

**CABINET**—Size 6" x 7" x 9½", metal compact, hinged cover, crystallized finish. Completely shields the receiver. Also ideal for portable use.

**RANGE** 15 to 200 meters—4 plug-in coils are supplied with each receiver.

The "EAGLE" completely wired and tested. Price. **\$11.95**

Complete set of Tubes tested in receiver. .... **\$ 3.00**

**GROSS RADIO, Inc.,**

51 Vesey Street Dept. S New York City  
Tel. Barclay 7-0161

Fig. 7. Gross "Eagle" ad in February 1934 *Short Wave Craft*

selected by four plug-in coil sets, the range being given as "15 to 200 meters" by Gross. Gross advertised an early form of "band spreading" by the use of a separate front panel mounted capacitor.

When first introduced, the Eagle was offered in kit form for only a brief time. Gross then warned that to duplicate the Eagle would cost "three or four dollars more than the completely wired and tested set." Later, perhaps in an effort to boost sales to those whom Gross termed as having "very limited means", the company lowered the assembled price down to \$10.95. While Gross only listed the Hawk for less than a year, the Eagle appears to have stayed with the company for nearly three years. First introduced in the winter of 1932, it last

appeared in print in October of 1935, a long run for a simple set. It may be the Eagle was simply pushed aside by the appearance of the new Hammarlund Super Pro and Hallicrafters Super-Skyrider sets, also sold by Gross.

These sets, along with the Gross transmitters, were adver-

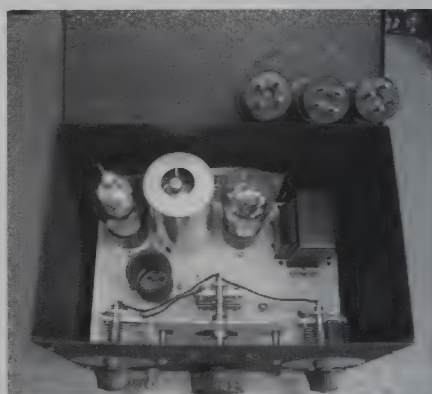


Fig. 8. Gross "Eagle", author's collection

tised in the back of *QST* for a number of years, no doubt inspiring the young ham to deliver many a newspaper, or mow many a lawn in order to spring for a new set. The Gross sets were unapologetically simple for the day, and while eclipsed by contemporary offerings of Collins, National and Hammarlund, they were affordable for the beginning radio amateur, an important consideration for that era.

## THE CW/CB-25 TRANSMITTERS

Perhaps the best-known Gross product of the day was the CW-25 "Beginner's Transmitter". First introduced in February of 1934, the set was offered until March of 1937. Larger, high power sets, like the CW-50, CW-55 and CB-100 (50 and 100 watts of output respectively) were later available, but never reached the popularity of the 25 series. The CW-25 was offered as both a kit with one set of band coils for \$13.95 (less tubes), and fully wired and tested for \$14.95. The CW-25 was a simple, if not inexpensive, way for the radio newcomer to get on the air. While \$13 sounds cheap today, in 1931 it was a far stretch for the average radio amateur. Bill Orr W6SAI writes "In those dark days of the depression, however, this sum was equal to a week's wages to some and was only a theoretical concept to the many unemployed."

Still, the CW-25 was a great bargain to the average ham, offering 50 watts input, with about half that power output on the 160 and 80 meter bands, lowering a bit on 40 and 20 meters. A four band transmitter in one compact chassis, with what was considered good power output for its day, must have been pretty tempting

for the new ham. Gross also offered a power supply kit for the CW-25 for \$8.75, or 50 cents additional if wired. Plug-in coils for other bands were available at the cost of 75 cents per coil. The Gross used three coils per band, so for the total cost of \$27 one had a full four band set, complete with power supply.

The CB-25, the "B" standing for class B fone operation, was offered for the princely price of \$66 less tubes. Wired and tested units cost an additional \$10. With the CB-25, the proud owner received a small desktop rack to hold the chassis, a power supply deck with modulator circuit, and a metering panel. One could also buy these parts separately, if desired. In the Gross design, the rack stood about 24 inches tall, with the RF deck located at the top of the rack, and the power supply below. A metering panel, with two large Gross labeled Weston panel meters, was located directly below the RF deck.

## THE CW/CB-25 RIG IN DETAIL

I am able to speak in some detail on the CB-25, as I am fortunate to have one in my hamshack (Fig. 9). Formerly owned by Bill Orr W6SAI, the unit was gifted to my friend John Rollins W1FPZ sometime in the late 1990s, with the provision that John could have the unit if he were to restore it and send photos to Bill.<sup>9</sup> Needless to say, John was not about to let a deal like that go through his hands. He was prepared to fly out in his private plane to pick up the rig directly from Bill in San Francisco when fate intervened. A friend who had to make a cross-country journey stepped in, and offered to drive out to California and retrieve the rig for John. Soon

the rig arrived back in John's workshop in Arrowsic, Maine where it underwent a full restoration, Rollins style.

Any correspondence between John and Bill seems to be lost with John's passing, but John never ceased to proudly point out the rig when showing a visitor his hamshack. I saw it during my many visits, ready to be switched on at any moment with authentic Gross coils for all bands neatly stacked atop the cabinet. After John's passing in March of 2008, the transmitter entered my care.

The CW/CB-25 was quite robustly built in the tradition of the day, starting with the steel chassis, finished with the classic black crackle paint. The three air variable capacitors featured prominently on the front panel were General Radio products, as were the dials, which were printed with the Gross lightening bolt logo. Such quality was surprising for a bargain kit of its day because General Radio was well known as a manufacturer of very high quality parts and equipment, hardly

what one would expect to find in an entry level amateur rig. Bill Orr W6SAI, writing in the February 1977 issue of *CQ* magazine, speculated that there were some \$30 worth of parts in the CW-25 and marveled how Gross could sell the complete set for a mere \$13.

Underneath the steel chassis the layout is a very traditional design. Straight-line heavy 12-gauge tinned wire was used for the ground and RF bus, and 14-gauge black insulated wire used elsewhere. A mixture of both ceramic and fiber sockets was used for the plug-in coils, vacuum tubes and electrical connections. Two air variable capacitors, equipped with "arrow instrument knobs", were mounted on the rear of the top chassis, and were used to neutralize the buffer and final stages.

Functionally, the CW-25 and its more expensive fone cousin, the CB-25, are quite identical on the RF decks; it is only in the power supply and modulator that the two differ. We'll start with the RF deck first as it is common to both models, and discuss the CB-25 power supply deck later.

The RF circuit of the CW/CB-25 was based on the then popular type "46" tube, and the design was often referred to as the "46 job". Starting from right to left on the RF chassis, a type "47" tube was used as a crystal oscillator as it would easily run on 160, 80, or 40 meter crystals. The 47 was originally designed as an audio pentode, but would provide decent RF output at 300 volts in a crystal oscillator. Output of the 47 went to a type 46 used as a buffer stage, which was then neutralized for a vertically mounted capacitor located almost directly behind the tube. The buffer output was then directed into a pair of type



Fig. 9. Gross CB-25 transmitter, author's collection.



46 tubes in a parallel amplifier arrangement, with another vertically mounted capacitor for neutralization. A plug-in coil was used for each stage, oscillator, buffer and output, hence the need for three sets of coils per band. The crystal holder was mounted on the right front of the top panel, in easy reach of the user, and Gross sold both the crystal holder and blank (you ground your own crystal in those days) for one dollar each.

During the tune up process, one used either an external meter, plugged into the jacks on the front panel of the RF deck, or the tried and true light bulb with an inductive loop of wire. Each stage was loaded and tuned to resonance, with the one caveat being that the phone jacks, insulated from ground, were hot with plate voltage! The CW/CB-25, like most sets of the day, was designed for a high impedance balanced antenna, so the link coupled output, again via a plug-in coil, went directly to a set of porcelain insulators on top of the chassis.

The modulator circuit on the CB-25 is a classic design that appears to have been taken straight from the early ARRL handbooks. A type "57" tube was used as the first gain stage in the speech amp, driving a single type 46 tube. The output of the single 46 was then sent into a pair of type 46 tubes in push pull, which drove the modulation transformer. Gross had designed the set for use with a carbon microphone, so the resulting audio was anything but "hi-fi". Still the set did work, and offered a moderately priced entry into the fone band. A pair of type "83" mercury vapor rectifiers completed the rest of the tube complement on the power deck.

Connection between the two chassis was via a cable running

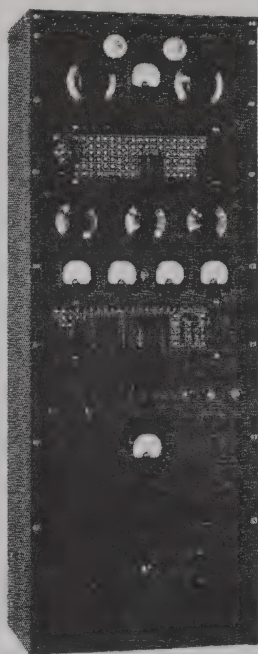
from the power supply to the jack on the rear of the RF deck. A set of "wander" leads were used on the front panel meters to switch in, measure and tune the various stages of the transmitter. A lower power meter on the right was used with the oscillator and buffer sections, with the higher power meter on the left measuring the 46 RF amplifiers wired in parallel. Keying was made via the front panel jacks, and a set of insulated dummy plugs was used to block the following sections when tuning.

Contrasted with the Collins 32B rig, selling at \$125, the Gross rig was a bargain. Sadly, it appears that few of the CW/CB-25 series survive today. It is unknown if this was the result of poor sales or just the ravages of time.

## THE GROSS HIGH POWER SETS

During the long run of the CW/CB-25 series, Gross also introduced some new and higher power transmitter sets. Still following the Gross nomenclature of CW and CB, with the input power following as digits, these units employed the newer high power tubes that were being introduced into the amateur market.

The top of the Gross transmitter line appears to have been the short lived CB-350, which used a pair of Taylor T55s in the RF output (Fig. 10). In the modulator, a pair of RK31s, in class B, was used to develop "100% modulation". Gross claimed the CB-350 had an input power of "350-400 watts", but did not list the output. Band coverage for the unit was stated to be 1.7 to 30 Mc, again, via plug-in coils. The design, a rack system, was interesting in that it included the antenna tuner in the top of the



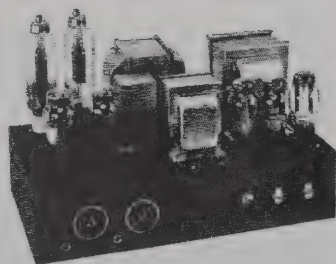
Bulletin upon Request Giving Full Details and Amazingly Low Price

## NEW!! GROSS CB-350 RADIOPHONE TRANSMITTER

More and more operators are realizing that only in a GROSS Transmitter can they obtain APPEARANCE, QUALITY, PERFORMANCE and VALUE such as they receive in the CB-350. A really high power phone at an *Amazingly low price*. Truly the "more watts per dollar" slogan takes on a new significance.

- R.F. TUBE LINE UP — 6L6G crystal oscillator, buffer or doubler one T55, class C amplifier two T55s
- POWER SUPPLIES — 1400-1500 volts at 300 M.A. 700 volts at 200 M.A.
- SPEECH AMPLIFIER — Four stage high gain for use with high impedance microphones, self contained power supply
- MODULATOR — Two RK31s are used in the class B modulator. 100% modulation, separate heavy duty power supply
- ANTENNA UNIT — Self contained antenna tuning unit included
- FREQUENCY COVERAGE — 1.7 Mc. 3.5, 7, 14 and 30 M.A.
- POWER — 350 to 400 watts input
- CABINET — Beautifully finished in battleship gray wrinkle lacquer

## NEW! BM-100 CLASS B 100 WATT MODULATOR



TUBE LINEUP: 3-6C5, 1-6N7, 2-6A3, 2-TZ90, 3-83.

INPUTS: One High and One Low Level High Impedance Input.

The BM-100 Class B Modulator Speech Amplifier will modulate 100% transmitters with inputs up to and including 330 watts input. ■ The unit is completely self contained on the one chassis and includes high gain Speech Amplifier and Dual heavy duty Power Supply. ■ The class B output transformer will match R.F. loads of 3300, 4400, 5000, 5880 ohms. ■ Chassis size: 19" x 11 x 4 1/2. Weight 70 lbs. ■ BM-100 Modulator used in CB-350 Radiophone transmitter is here illustrated, the BM-100 is very similar in appearance.

Completely wired and tested in our laboratory, **\$59.00**  
less tubes.....

Matched set of tubes..... **\$12.50**

WRITE FOR FREE NEW CATALOG ON HAM  
AND P. A. EQUIPMENT

20% DEPOSIT WITH ALL C. O. D. ORDERS

REMIT BY M. O. INCLUDE POSTAGE

Cable Address: GROSSINC

**GROSS RADIO, INC., 51 VESEY STREET, NEW YORK CITY**

Say You Saw It in QST — It Identifies You and Helps QST

87

Fig. 10. Gross Radio ad in QST, November, 1937.

rack. Metering was also extensive; I counted a total of eight meters on the set, including what appears to be a set of amp meters in each

leg of the RF output. I've only found one mention of this set, from November of 1937, so it appears to have not found commer-

cial success, perhaps not a surprise given the high cost of such a set and economic conditions prevailing at the time.

In terms of duration, the longest running high power Gross set appears to have been the "CB-250". The CB-250 was a CW and class B fone set with a power input of 250 watts that covered, via plug-in coils, the 1.7 to 30 Mc bands. The transmitter used a pair of Taylor TZ40s in both the modulator and RF output section. This set, first introduced in September of 1938, was offered until the last *QST* ad in 1941.

Interestingly enough, Gross seems to have never listed a price for the larger, high power sets. I suspect this was because these sets, costly as they would be, were built to order rather than on "spec". The exception to this pricing policy seems to have only been in the last days of Gross radio, when the "Clearance Sale" ads were running.

## WINDING DOWN

Be it the Second World War, or perhaps just a downturn in business, the October 1938 *QST* carried a very different ad from Gross. Rather than his usual by-line touting the features and benefits of his latest sets, Jerry chose to share an unusual message with *QST*'s readers. "Opportunity" screamed the headline "To Purchase At Bargain Price," "A long-established retail radio store."

Perhaps Jerry decided to enter into supplying the wartime need for communications gear, for the ad also read "This sacrifice is made because our full time will be devoted exclusively to manufacturing." Or perhaps Jerry saw the clouds of war, and with it the ban on all amateur radio transmissions. In any case, after the "Op-

portunity" ad, Gross only placed a total of nine more ads before they were gone forever from the pages of *QST*. Each ad was progressively smaller than his early full-page spreads, and the final ad, appearing in February 1941 *QST*, advertised a "Clearance Sale" on all "Well Known Gross Transmitters" (Fig. 12).

## THE MYSTERIOUS LEGACY

So where did Jerry Gross go, and what happened to Gross Radio Company? At this point, I really don't know, for it seems that our story ends here. In the process of researching this article I contacted Leeds Radio, Jerry's former employer, searched the *New York Times*, and employed the kind services of a friend, Bob Ballantine W8SU. Bob seems to have discovered that Jerry was born in 1898 and passed away in November of 1973.

The last mention I found of the Gross Radio Company was in the February 23, 1945 issue of the *New York Times*, which reported a landlord dispute between Gross Radio and the building's owners. In part, the article read "two workers from the Gross Radio Company hiked six floors to an equally cold and damp shop at 8

***Opportunity***

TO PURCHASE AT **BARGAIN PRICE**

A long-established retail radio store. This sacrifice is made because our full time will be devoted exclusively to manufacturing.

**GROSS RADIO, INC.**

51 Vesey Street      New York City

Fig. 11. Gross Radio ad in *QST*, October, 1938.



**CLEARANCE SALE!!**

**WELL KNOWN GROSS TRANSMITTERS**

*Completely Wired and Tested*

95 WATTS C.W.....	\$ 64
95 WATTS PHONE & C.W...	110
150 WATTS PHONE & C.W...	200
250 WATTS PHONE & C.W...	295

*Descriptive Bulletin on Request*

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**2½ METER TRANSCEIVERS**

**ABBOTT DK-2...\$16.50**

Portable Battery operated. Price is less Tubes and Batteries

**ABBOTT MRT-3...\$28.20**

**HI-POWER—20 WATTS**

For Mobile or Fixed Station. Price is less Tubes and Power Supply

**GROSS RADIO INC.**

51 Vesey StreetNew York City

Fig. 12. Gross Radio's last ad in *QST*, February, 1941.

West Eighteen Street to help meet another Navy contract.”

Apparently the owners of the building had shut off the heat and elevators in the structure on Washington's Birthday. Gross, under pressure to fulfill the contract, had unsuccessfully implored the Navy to have the building's owners turn the utilities back on. The article further mentions that the Gross Company had “seven employees”, but only two felt “hardy enough” to work without heat and elevators. So perhaps Jerry did get his wish after all, Gross Radio may have successfully made the transition from the ham to the military world.

You'll note that I have relied heavily upon *QST* magazine in reconstructing the history of Jerry Gross's companies. The reason for this is simply that little information remains other than product sheets, ads, and schematics. Even more rare than printed ephemera is the actual Gross produced equipment. For a company that had nearly a 20 year run in the radio business, and consistently placed large monthly ads in *QST*, it is rather surprising how few of

Jerry's creations remain. Raymond Moore, in his excellent “Transmitters” book<sup>10</sup>, devotes no less than seven pages to the Gross Company, and notes that Gross was “one of the major amateur transmitter manufacturers of the 1930's.” Admittedly many of the early kits were rather simple, and undoubtedly in the ham tradition of the day, were later disassembled for parts as the amateur advanced in the hobby or technology moved forward.

If you have any additional information or recollections, or if you own Gross gear, then I'd very much enjoy hearing from you. I would be especially interested in anything that can help clear up the mystery of what happened to this great piece of American radio history.

## END NOTES

1. While 1931 appears to be first year for what was known as the Gross Radio Company, it is quite possible Jerry Gross had been in partnership in an earlier firm, the name “J. Gross & Co.” would seem to indicate the latter.
2. *QST*, August 1927.
3. Park Place was a rather interesting address for a budding radio manufacturer. During the early 1930s, Hugo Gernsback, of Gernsback Publications, famous for his own radio business, The Electro Importing Company (later known as EICO), as well the *Radio Craft*, *Short Wave Craft*, and *Radio News* magazines, maintained editorial offices right down the street at 99 Park Place.
4. *QST*, April 1927, Teleplex company ad. Bill Pierpont NoHFF also made note of the Teleplex company in his work “The Art & Skill Of Radio Telegraphy”.
5. A check of Google Street View seems to confirm this hypothesis; 323 East 83<sup>rd</sup> Street is a multilevel

residential apartment building. New York City tax rolls list the building as co-op apartments, and the build date is given as 1910. However, it is possible that the ground floor may have been commercial space.

6. *QST*, October 1929.
7. *QST*, October 1931.
8. "Transmitters I Wish I Owned" by Bill Orr W6SAI, page 34, *CQ*, February 1997.
9. *AWA Old Timer's Bulletin*, February 1998, "Restoration Of A Gross Company Transmitter" by John Rollins W1FPZ, pages 26-28.
10. Raymond S. Moore, "*Transmitters, Exciters and Power Amplifiers 1930-1980*". Key Largo, FL: RSM Communications, 1996.

## ACKNOWLEDGEMENTS

John Rollins W1FPZ - For his kindness and generosity, he was truly one of the great gentlemen of radio.

Tim Walker W1GIG - Tim patiently and diligently copied and forwarded over records, notes and information from the Rollins estate.

Rob West KC8DDH - For his editorial review, suggestions, and help in filling in the blanks of the Gross Radio Company.

Nancy Strunk - For her editorial assistance, review, encouragement and wisdom.

This article was peer reviewed.



## ABOUT THE AUTHOR

**Bruce J. Howes, W1UJR**, was born and raised in the southern tier of New York State, into a family well known for a fascination with mechanical devices. His grandfather was a welder, business owner, and International truck dealer, while his father ran a construction equipment repair facility in Okinawa during the Korean War. So it was no surprise that Bruce grew up tinkering with machines and old radios. What became a hobby as a young man quickly escalated into a profession. Calling himself a "serial entrepreneur", Bruce is on his third business venture, two in the automotive field, straddling a brief stint in a marine electronics company.

Bruce's passion for radio began at a young age as he would stay up late hours to listen in to station WBZ on his parent's old RCA tube receiver. The radio bug bit deep and he became a shortwave listener at age 12, progressing to extra class radio amateur in his early thirties. Bruce is a Life Member of the American Radio Relay League, and a Life Member of the Antique Wireless Association.

After selling his business in Buffalo, NY in 2000, Bruce now lives in Maine where he jokes to have opened another business in 2003 to support his radio and sailing hobbies. In appreciation for all things old, he resides in a 1860's home built for a Maine sea captain. His library, radio shack and repair bench are located in a somewhat newer structure on the property, of the 1920s vintage, affectionately known as the radio barn.

Bruce likes to say that he has regressed in the radio hobby, first starting out with amateur satel-

## Gross Radio

lites, building a fully automated digital satellite ground station. His current fascination is with early 1900s radio apparatus, with a primary interest in the preservation and operation of vacuum tube ham gear from the 1920s to the 1940s.

Much of his radio time is spent in the documentation and restoration of such gear. Early prewar gear, especially home brew, holds a special place in his heart, and he has never been able to say no to anything with black crackle paint and vacuum tubes. He hosts a website of his efforts, [www.W1UJR.net](http://www.W1UJR.net), with a popular subsection entitled "Bruce's Bench" where his latest projects and restorations are posted. In his spare time Bruce enjoys sailing, wooden boats, nautical history, and perusing dusty, old bookstores and antique shops along the Maine coast.



Bruce J. Howes



# AWA Review Meissner Regenerated

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## ABSTRACT

Could Alexander Meissner, an Austrian engineer working for the Telefunken Company of Berlin at the turn of the 20<sup>th</sup> century, be the real *Vater der Regeneration*? On the American side of the pond at least, it seems that the various contributions of several players including Armstrong, Meissner, Langmuir, de Forest, Round, Franklin and even Tesla's assistant Fritz Lowenstein, have been weighed and the regeneration litigation has been long settled. History has shown that De Forest got the legal nod while Armstrong got the heartfelt scientific and technical endorsements. Meissner however, never got the recognition that he might have in the litigation and subsequently in print because of the outbreak of World War I. His work deserves a fresh look in the context of the years between 1911 and 1914 when regeneration was discovered and applied in practical circuits using the early valves.

There has been a lot of excitement of late in the AWA community concerning the patent litigation and final outcome of the battle over deciding just who the "Father of Regeneration" was. Most of us now know that deForest is the legal recipient based on a final Supreme Court ruling on 21 May 1934 and that Armstrong is the sentimental and as many think (including the IRE in 1934), the rightful holder of that title. I want to introduce another contender, Alexander Meissner, an Austrian Engineer/Physicist. I will set the historical stage and introduce a series of patent schematics all from the 1912-1914 period and will attempt to explain the significance of each. I also like building the old circuits I will bring some of that into the story too.

First let me first say that there is very little record of the exact thinking or intent of the inventors in the published notes, patents and judgements, and the wording of the patents are clouded by plenty of extra lawyer-inspired jargon. Also, I do not speak German although I have been to Germany several times and I had some help--my son takes German in school and actually just got back from Neustadt Weinstrasse on a student exchange. I had some guidance and fantastic reference material sent over to me by Hans Thomas Schmidt, from Germany. Hans did not give me too much hope on being able to understand the circuits in context in some of the German sources he recommended. "I think, a translation into English can be difficult. There are a lot of special vocabulary and you can understand them only in context with the electrical function."(1)

Finally; legally in many of the discoveries, the omission of even a single word can change the entire outcome of a court decision. So rather than trying to interpret the patent text or decisions, instead I will attempt to let the circuits themselves speak to us.

## A NEW TRANSMITTER

I became interested in building some of the early valve oscillator circuits when I began participating in the AWA's 1929 Bruce Kelly QSO Party a few years ago. I had a lot of enjoyment building up the TPTG and Colpitts oscillators and putting them on the air. It is interesting how this contest has encouraged folks to get back on the bench and recreate the old time circuits. I remembered some of the radio journals that I had access to in high school in the early 1970's, in my hometown Canton NY, visiting the St. Lawrence University library. I vaguely remembered the illustrated schematics of the DeForest and Marconi radio-phone circuits.

St. Lawrence itself is actually historic in radio terms in that it had one of the first operational AM radio stations in the country. WCAD was broadcasting on 360 meters on the college campus in 1922. The College Station was later granted KSLU by the FCC to honor this historic station (only one of very few K calls issued east of the Mississippi).(2) This meant that radio physics was taught in depth and they had an extensive collection of early radio books.

When I wanted to do up a new transmitter for the *Kelly* four years ago, I looked back, not at *QST* but at these older patent and journal sources. Any experimentation into these old circuits invariably leads to questions, lots of trial and error and even some smoke. Not every detail is revealed in a patent diagram! Two years ago I showed up in the contest with something called a Meissner Oscillator, which caused some kind of commotion (Fig. 1). People had heard of Colpitts and Hartley, but who was Meissner and what was a *Meissner Oscillator*? Was it even legal to use

one of these in the contest? Looking at my schematic you can see that this oscillator is a bit different, but at least the keying and antenna coupling look familiar to those of you that have built up some of the old time transmitters.

Before we get into the circuit, it might be a good idea to investigate this radio pioneer, Meissner, who some say was cheated out of his rightful place as the *Father of Regeneration*. Hold it! We just got finished arguing about Lee deForest and Edwin Armstrong and now you want to bring in a third player? Actually beyond Alexander Meissner (Telefunken Co.), a few more people were in the fray, including H.J. Round and C.S. Franklin (both Marconi Co.), Irving Langmuir (General Electric Co.) and finally Fritz Lowenstein (Tesla's head assistant). Somebody in this crowd of giants is the real guy, no doubt.

Of course Fleming's *valve patent* (3) and Fessenden's *heterodyne patents* (4) along with deForest's *Audion device* (5) are the critical pieces that actually fueled the explosion to come in 1912.

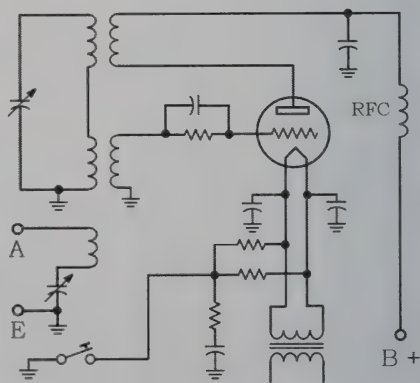


Fig. 1. Meissner Oscillator built by the author.

## RADIO AT THE DAWN OF THE VACUUM TUBE

In the early 1910's when vacuum tubes were first being considered for use in detector amplifiers (sometimes called *relay valves*), it was already established that the most reliable wavelength for transatlantic radio communications was 5000 – 8000 Meters (35 – 55 kHz). This is where Marconi's large shore stations operated at the time. (6) Ship to Shore and Ship to Ship operated above this between 300 and 600 m. Damped wave transmission was already mature and several reliable ways of producing radiotelegraphy were already in use. These included the various spark and arc systems and much work was progressing on large high frequency alternators. Telefunken would have machines capable of producing 100 kW on 2000 meters by the end of 1912 based on a novel ferro-resonant frequency multiplication scheme. These were developed mostly to communicate with the far-flung colonies of an emerging world power - Germany. (7)

Radiotelephony on the other hand was still novel and fairly difficult to produce with the spark gear or machines, although by this time several manufacturers had produced sets including Telefunken in Germany. These radio-*phones* had a microphone that was usually cleverly insulated so that the operator did not receive an RF burn to the mouth. This was required because of a simple connection of the microphone in series with the bottom of the antenna tuning or coupling coil ground connection. The other system called *loop* or *absorption* was being used as well. These were fairly primitive amplitude modulation methods.

Radiotelephony is by nature,

more suited to shorter range applications where lower power can be useful. Indeed all of the early valve demonstrations were made quite dramatic by stressing the use of the new technology as a commercial radiotelephony avenue. By 1910, radio broadcasting had already been conceived, thanks to Canadian-American engineer Reginald Fessenden and his 1906 music broadcasts. So it makes sense that the first use of the new vacuum tube technology would be to promote improved radiotelephony, not radiotelegraphy.

It is also interesting that shorter wavelengths were used in the Meissner experiments. Beyond dramatics, modest power and higher frequencies allowed the use of smaller coils (and antennas) allowing the production of portable tabletop demonstrators (and patent models) to be developed. Meissner used 600 meters (500 kHz) for most of his experiments in 1913. (8)

## MEISSNER BIOGRAPHY

Alexander Meissner was born on September 14, 1883, in Vienna. His father was a writer and theater critic from Pommern. After high school, he studied electro-technology and mechanical engineering at the Vienna University of Technology and later physics at the University earning the doctor of technical science degree in 1902. In 1907, he started working at Telefunken in Berlin.

He was promoted to intermediary between engineers trained in industrial engineering and the few real scientists. He improved the design of antennas for transmitting at long wavelengths, devised new vacuum tube circuits and amplification systems, and developed the heterodyne principle for radio reception. In 1911 Meissner de-



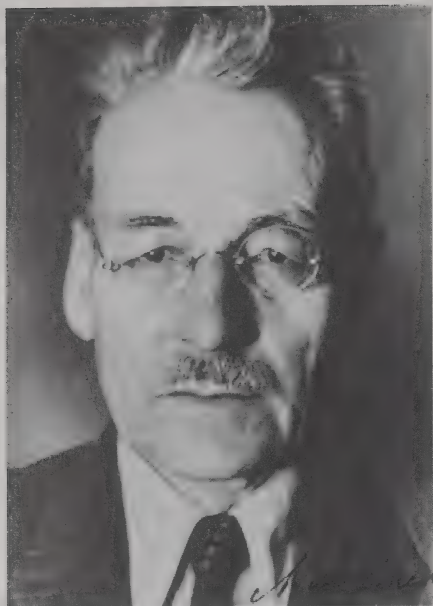


Fig. 2. Alexander Meissner

signed the first rotary radio beacon to aid in the navigation of the Zeppelin airships.

After 1912, a consortium of firms from AEG, Siemens & Halske, Telefunken and Felten & Guilleaume had bought the Lieben tube patent. With this tube Meissner invented a feedback high frequency generator in 1913. In 1912-13 he produced a flurry of new radio circuits some of which we will concentrate on in this article. Many of his later patents in the 1920's show new circuit ideas, which are quite ingenious like double balanced and push-pull crystal sets, foreshadowing modern integrated radio circuits.

Before the war, Telefunken and Marconi had negotiated a German-British patent parity agreement. During World War I however, the patent protection of Britain and the USA was suspended and many of his patents had to be re-registered post-war with much later dates. Thus he was basically thrown out of the 4-party regen-

eration patent battle by a technicality! After 1928 Meissner served as a professor at the Technical University of Berlin. In 1930, he entered the research institute of AEG; altogether he attained over 200 patents and by World War II he was quite renowned. He was married and had a son. He died on January 3, 1958, in Berlin. (9,10)

Let me summarize that Meissner was an engineer with additional background in physics with skills in radio and amplifier design. (8) His genius also included antenna and antenna superstructure design, quartz crystal structures and the development of early radio direction finding techniques and transforming them into real systems. As an example, the German geolocation guidance stations, which guided the Zeppelins, were based on his rotating beam beacon concept. (7) This clever system used directional beams, but also synchronization and timing and thus it is the grandfather of both LORAN and GPS.

## THE LIEBEN VALVE

The hot new radio devices in 1910 were the American, Lee deForest's Audion *hard valve* and the German, Robert von Lieben's *soft valve*. One of Meissner's first tasks for Telefunken was to try to evaluate these new valves for use in improving radio circuits and developing commercial applications. (7) DeForest had a beautiful patent on the Audion. But since there was no high license fee on the Lieben valve, and it had been made available to Telefunken through the patent sale, that device was what received the most attention from Meissner. Telefunken had a policy of fast development and profitability. As

many new radio circuits as possible were to be developed and put into protection and *production*. Telefunken and his boss Count Von Arco did not want Meissner to study or explain the circuits and effects in a running dialogue as with deForest and Armstrong;

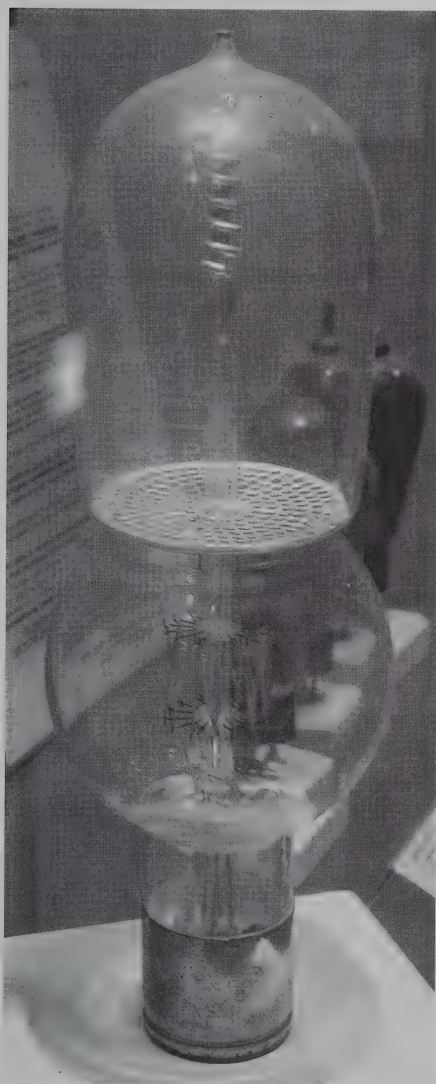


Fig. 3. The Lieben Valve

Photo Courtesy H.T. Schmidt Copyright 2009

they expressly wanted him to drive profits. (7)

Some more detailed information on the Lieben valve can be found on Hans Thomas Schmidt's website (1) Telefunken was not the only licensee of the Lieben's patents. There were three other manufacturers, Siemens, Felten and Guillaume (later TeKaDe) and AEG. The patents can be seen on his homepage and also the consortium trust between the manufacturers and Robert von Lieben. A very significant patent is the first Lieben patent from 1906, which describes audio amplification in a vacuum tube with electrostatic or magnetic control.

Before the winter of 1913/14, pumping a valve to a hard vacuum was not yet possible. All earlier pumps worked with mercury. Von Lieben obtained and used a rotating mercury pump from Wolfgang Gaede, invented 1905. In 1913 Gaede invented the molecular pump which finally made high vacuum tubes (hard tubes) possible. One of the first of these new pumps reached the USA very early. (1)

Let's take a look at the technology in the Lieben valve. The Lieben valve or ("translated literally as Love Relay") is a *soft* valve meaning it is not a high vacuum *hard pumped* device like an audion but it is in fact a mercury vapor or thyratron triode, with an imperfect vacuum. This valve, from 1906, was originally designed to be used like a relay for weak telegraph signals. A small positive signal on the grid causes the tube to conduct in its plate. In its original form, it is not regarded as a linear amplifier but was later adapted to the amplification of wireless receiving sets and finally in 1913 applied as an oscillator and regenerative detector by

Meissner.

"It must be at once mentioned that these are not high vacuum bulbs, an atmosphere of mercury vapor being purposely provided by the small piece of mercury amalgam shown sealed into the small side tube at the bottom of the tube sometimes called an *appendix*. The result of this vapor and the oxide-coated Wenelt (heated) cathode is that the tube in operation shows a continuous blue glow. The filament is a (wound) platinum strip, about a meter (3 feet) long in all, 1 mm. (0.04 inch)

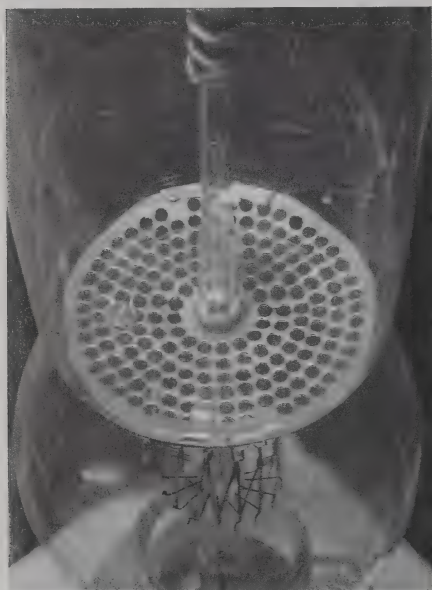


Fig. 4. Lieben Valve detail.

Photo Courtesy H.T. Schmidt Copyright 2009

wide, and 0.02 mm. (0.002 inch) thick. It is thinly coated with a mix of calcium and barium oxides, and is brought to a bright red heat by a current of about 2 Amperes from a 28 to 32 volt storage battery, the current being regulated by a 5 ohm variable series resistance." (Note: necessary control,

regulation and filtering circuits such as rheostats are usually left off patent diagrams for clarity). Considerable heating power is, therefore required; and the source of this power must be an extremely constant one. The plate circuit is fed from a 220-volt source, which may be an ordinary dynamo with choke coils in the supply leads to cut down on the incidental noises." (11,12) (Note: again never shown in the patent diagrams but one wonders how you would use a dynamotor to run a receiver without filtering!).

The zigzag cathode, punched aluminum grid and spiral plate structures all look technically excellent, showing the quality commercial construction possible at Telefunken, even on new device types.

"The best operating point is usually where blue ionized mercury vapor begins about one to two cm over the grid. While operating the tube it could be necessary to heat up the sodium amalgam (sodium-mercury alloy) in the *appendix* of the tube to raise the vapor pressure of mercury in the tube for better performance. Later Lieben tubes had a grid made of wire instead of the punched aluminum plate. The Lieben tube with the sheet metal was named "Kraftverstärker". Both variants had also been built in a smaller version of about 195 mm height."(13)

## RELAY (AURAL) AMPLIFIER

It was soon demonstrated that the reliability and "range" of damped wave telegraphy communications could be increased by a factor of 10 (20 dB) with a single audio amplifier valve attached to a high performance tuner and detector. This was a tremendous



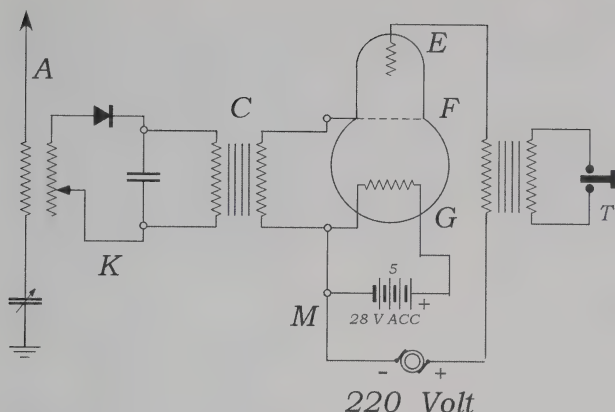


Fig. 5. One of Meissner's Amplified Receivers

\*The Lieben Valve is heated with 28 - 32 VDC with rheostat. The Plate voltage is supplied by a filtered Direct Current Dynamo.

advance for spark. Several patents are published in 1911 and 1912 based on the Audion and Meissner applies the high gain Lieben Valve with similar success.

Certainly the amplification of crystal detectors using vacuum tubes for aural reception was an important advance and several groups were working on this feverishly including deForest. But there also was quite a controversy as to what technology, gas relays or electron relays, was the best approach for amplified radiotelegraphy reception. With a gain of over 30, the Lieben valve not only drove headphones, but in cascade it could actually be used to drive sensitive mechanical relays. In November 1911, before the *oscillator*, Meissner was using the Lieben valve to detect and amplify spark transmissions.

## RF AMPLIFIER

Amplifying the RF before a crystal detector proved to be even more effective since it allowed two or more tuned circuits to be used in cascade before the detector, with the amplifier valve canceling out the losses. It was noticed that this amplifier sometimes was stable with predictable gain, sometimes produced tremendous gain and

sometimes oscillated. Lee deForest later argues that he spent a summer trying to keep his Audion from "howling"! If you remember the Barkhausen criteria, you know that you need only an amplifier gain of just over one and proper feedback and phasing to maintain continuous oscillation.(14) Even a diode can be made to oscillate due to negative resistance. So high gain devices like the Audion and Lieben valve

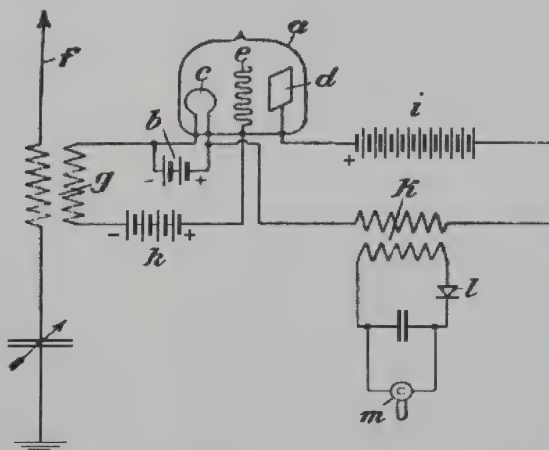


Fig. 6. HF Amplification - Otto von Bronk DRP 271059 Patent

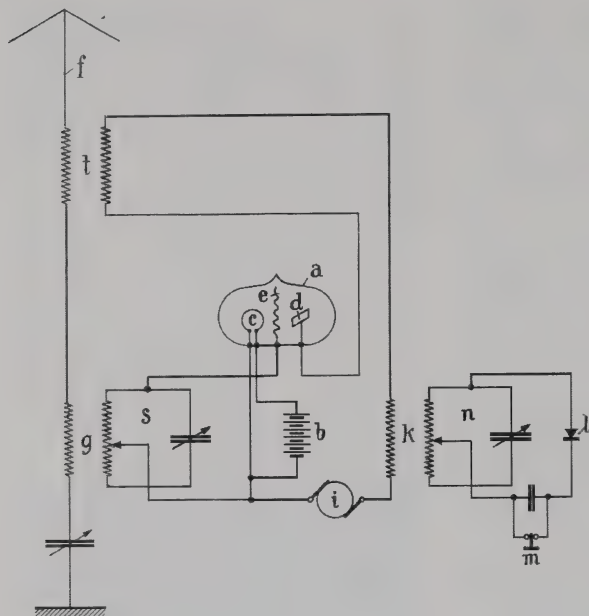


Fig. 7. Meissner (Regenerative Preselector) DRP 290256

were no doubt oscillating wildly in laboratories all over the world in 1912, and I might add - mostly by accident!

A schematic from Otto Von Bronks *Deutsches Reichspatent* DRP 271059, HF -amplifier, dated 1911 is shown below (Fig. 6). This was an early use of the Lieben valve as an HF (High Frequency) amplifier. Below this I show Meissner's *regenerative* RF amplifier DRP 290256 dated 16 July 1913 (16), (Fig. 7).

This radio circuit is an amazing accomplishment and Meissner in his patent, claims that it has improved performance over Von Bronk's HF amplifier. Regeneration is used to both increase the gain and the Q of the front end. There are no fewer than three tuned circuits between the antenna and the detector. This circuit looks very effective and if you wanted to have some fun, it is

worthy of adapting to the 1AD (one active device) Contest, sponsored by the Birmingham Crystal Radio Group, where it might possibly cause quite a commotion! (17)

## 1913 OSCILLATOR PATENT

Let's look at Meissner's first regeneration *oscillator* patent, issued in Germany, which is DRP 291604 of April 10, 1913 (18), (Fig. 8). This is an oscillator, plain and simple. Looking at the circuit, you have no doubt that this design exactly defines the in-

ductive feedback oscillator, which is today called the Armstrong Oscillator or sometimes simply the Blocking or Tickler Oscillator on this side of the pond.

The method of self-excitation of the valve Meissner originally termed "backcoupling"

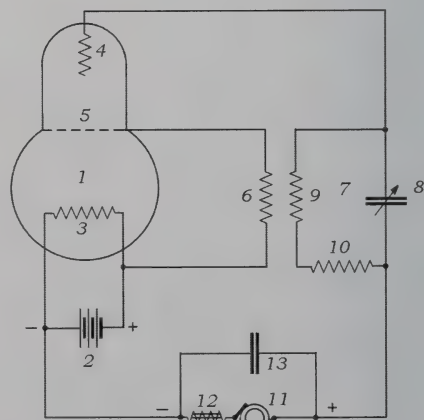


Fig. 8. April 10, 1913 Patent Oscillator

(Rückwirkung). It has since become successively known as “retroaction”, then “reaction” and finally regeneration. The use of retroaction is not entirely due to Meissner since Strauss, who collaborated with Lieben and Reisz, first mentions it in an Aus-

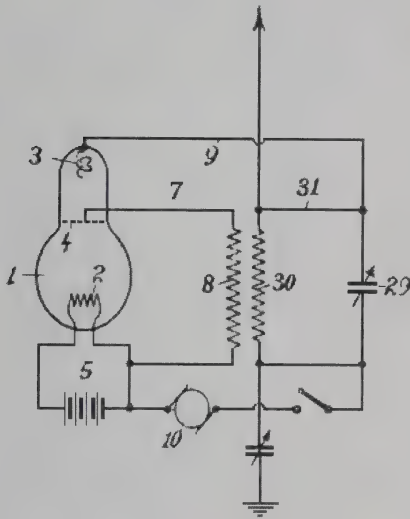


Fig. 9. Simple Tuned Plate Meissner Oscillator from a later (1914) Patent

trian patent of 11th December 1912. Strauss however, merely applied such retroaction for intensification of received signals (audio and RF regenerative amplification) and apparently did not consider the valve as being capable of use for generation. Armstrong, by a U.S.A patent of July, 1914, also protects the use of retroaction for valve generators. (7)

Notice how not all of the plate tank inductance is used for feedback. The tank has been split into two coils and only one coil is in retroaction. This is typical of the early Meissner oscillator designs and it finds its way into the receivers. Later Meissner designs also show 4 coils with two involved in feedback and a simplified version showing only two coils in the

more familiar Tuned Plate version (Fig. 9).

If you study Armstrong's first regeneration patent you see several very complicated circuits, some of which are inductive feedback types, some which are no doubt, TPTG oscillators, and a couple that have both at the same time! So I would put forward a notion that the first Armstrong Oscillator could just as well be the TPTG as the inductive feedback type. In any case, both are shown and both are described in the Armstrong patents. According to Meissner, the Armstrong retroaction patent was filed after knowledge of his own discovery. Notice that the Meissner circuit is lacking grid leak or grid bias control.

The early soft Lieben valves that Meissner used in his 1913 experiments did not hold up to use as an oscillator and the life of such a valve could be as short at 20 minutes of key down transmission (with no grid biasing). (7)

But actually this thinking is not entirely true. The Lieben valve was used with a negative grid voltage, even though this is hard to see in the diagrams. The grid was indirectly connected with the negative end of filament bias. The filament was heated up to 28V DC so consequently *most* of the filament wire has a more positive potential than the grid. (1)

The working time of the early Lieben valves was very short. They only operated at ratings for approximately 1 hour, but after removing, hanging the bulb upside down and cooling it, further use was possible. The addition of temperature control added to stability. (1)

In any case, Meissner was able to use the system to demonstrate radiotelephony communications over a 36 km distance in 1912 us-



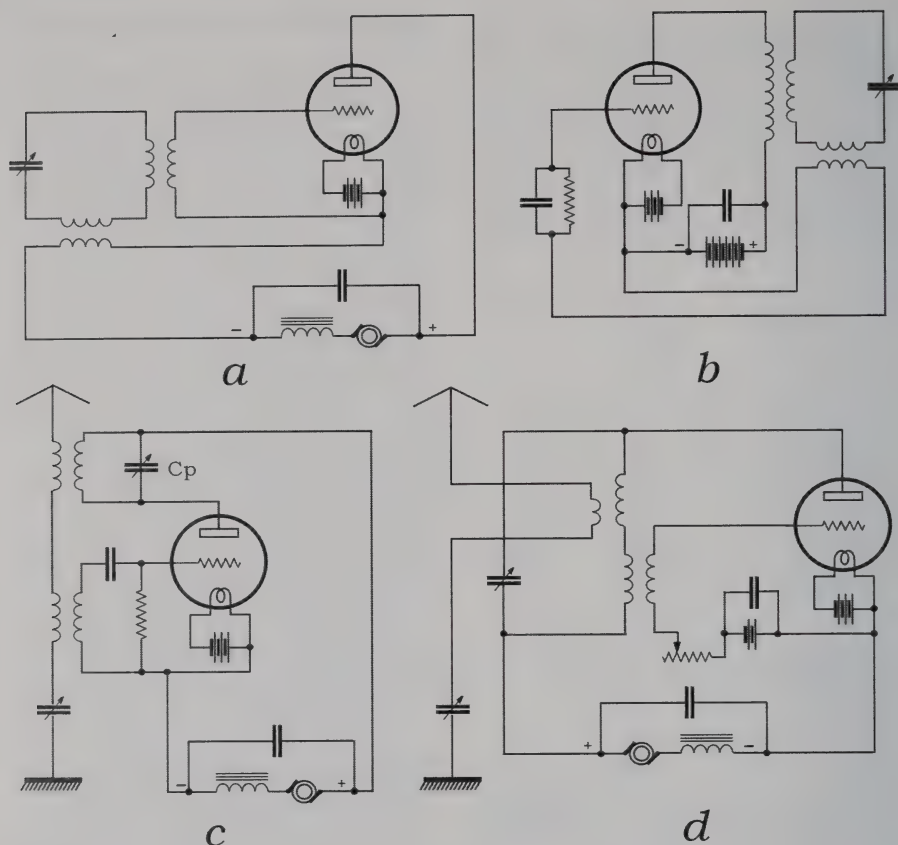


Fig. 10. Meissner Oscillator Variations

ing a 12 Watt oscillator based on the Lieben valve using a plate potential of 220 VDC.(7)

One more interesting point on the Lieben tube from Hans: The lieben tube was not a good high power transmitter tube. The output power was too low. It was mostly (likely only) used as modulator tube in machine transmitters or as external oscillator for heterodyne detector receivers. The last of them were used in the SS Vaterland (later Levanthian). On this ship the valve was also used as an audio amplifier. (1)

In the variations diagrams in Fig. 10, I show a couple of ways to grid leak stabilize the oscillator (b and c) and a fixed bias method

(d). Fixed bias or adjustable fixed bias as pioneered by Franklin in 1914 is appropriate and after 1915, basically all Meissner oscillator variations show grid bias control. Notice in c and d that the oscillators are an open type. (19) That is, they are supplying power to the antenna (load) with a great effect on the tuning. The natural resonance of the antenna can be used to tune the oscillator alone. The plate and grid coils in effect are both ticklers in that the resonance of the antenna and loading sets the oscillation frequency. Practically speaking, a plate capacitor ( $C_p$ ) or a grid capacitor or both can be added to force resonance in a more controlled manner. In

the radiophone circuits of the early 1920's typically they resonated the plate or grid but took power from the plate tank. For CW however, this coupling is best done from the cold side of the tank as with all self excited oscillators, a link giving

layout can be optimized, and the power can be taken off the plate circuit from an inductor that is not involved in the feedback process. The result is tremendous stability. The General Electric and Marconi Radiophones extensively

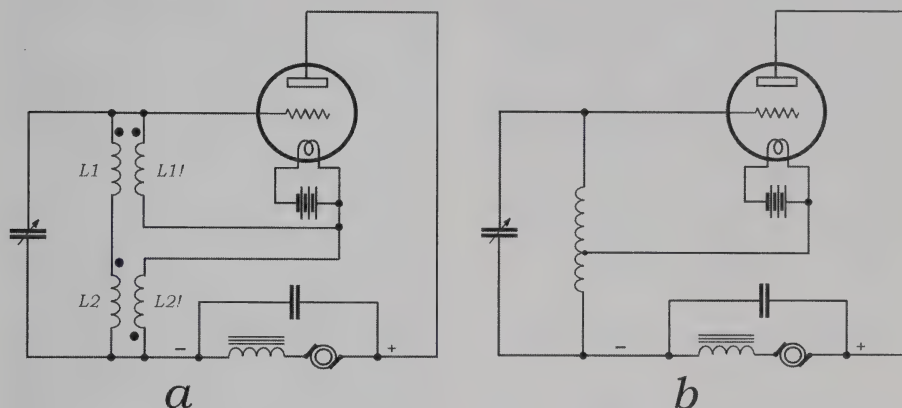


Fig. 11. Meissner compared to Hartley the best compromise on note and stability, especially into a modern 50-Ohm antenna match.

## MEISSNER'S OSCILLATOR

The Meissner type has the three critical LC oscillator characteristics of adequate gain, correct phase shifting (for positive feedback) and a frequency-determining circuit (resonant tank). These characteristics make it a stable continuous wave, low phase noise, oscillator. It actually is a very flexible circuit being a 4-port (or point) oscillator rather than a 3-port system like a Hartley or Collpitts. This means that the feedback can be adjusted independently of the tank inductance and Q and greater output and stability can be achieved over a wider frequency range. Notice that in some of the diagrams, 3 or 4 coils are involved. This splitting of the inductance allows the feedback to be independently applied in a more controlled manner. Thus,

use the 4-coil system throughout the late teens and early 1920's under license. Later, designers dispense with these and you generally see only two coils. The Meissner was preferred for communications receiver local oscillators throughout the 20<sup>th</sup> century, where a stable output over a wide range was required. Most hams of course followed the *Handbook* and the simpler to build single coil transmitter circuits like the Hartley. Speaking of \*Hartley oscillators, consider the simple transformation below.

## HOW IT WORKS

The operation of the Meissner oscillator is basically thus. Let us consider the classic Meissner 4-coil version shown in Fig. 11 (a).

\* It is fairly apparent that the Hartley is derived directly from this version of the Meissner. For an example of a famous amateur radio station that used the Meissner circuit in the 1920's: see <http://www.qsl.net/w5afd/5afd.html>

Notice how the plate and grid each have a coil much like a tickler coil. They are each independently coupled to the tank circuit in two pairs with one in anti-phase. Again, the grid and plate coils are neither magnetically coupled to each other nor to the other coils in electrical series with them. In fact the upper and lower sets of coils can be at right angles to each other or on separate decks of the transmitter. Resonance of course depends on the total series inductance of the two tank inductors and the standard resonance formula is adjusted to be:

$$f = \frac{1}{2\pi \sqrt{[(L_1 + L_2)C]}}$$

where  $L_1$  and  $L_2$  are the inductors in series on the tuned tank side. In a practical *\*closed* oscillator circuit, the actual oscillation frequency will be slightly different (lower) from the value provided by this formula because of stray capacitance's, internal losses (resistance) and loading of the tank circuit by the feedback coils. The load, which could be another (especially un-neutralized) valve stage, could also greatly effect the actual operating frequency. Most importantly and finally, in an *open* oscillator circuit where the load (i.e. a resonant antenna system) determines the primary operating frequency, *it* dominates.

Back to the operation of the oscillator...First we consider the grid at zero potential in respect to the filament. When plate voltage is initially applied current flows to the plate, and an electromagnetic

field is generated in the entire composite plate coil. (Even though  $L_1$  and  $L_2$  are in the negative side of the power supply, they are still in the plate circuit.) Based on the inductive ratio between  $L_2$  and  $L_1$ !, some inductive (magnetic) feedback will energize the tank to the resonant frequency. This through the 180-degree phase reversal of the two-coupled windings forces the grid negative through its top coupling network made of  $L_1$  and  $L_1$ !

The grid being negative with respect to the filament stops current flow into the plate. Thus the plate LC energy collapses on itself and again through a phase reversal it drives the grid circuit, but this time positive which starts the whole cycle over again. During every cycle, the grid potential oscillates back and forth between two extreme limits. The idea is that the plate current is in phase with the grid voltage. This is the positive feedback condition. (19)

It is also important that we understand the coupling effect and why Meissner took such great care to control it. Suppose the circuit shown is oscillating. If the coupling coefficient of the two magnetically coupled coil sets is gradually reduced, a given alternating grid potential in the coil  $L_1$ ! will require a gradually increasing alternating plate current flow in the tank coil  $L_2$ !. In other words the *looser* the plate to grid coupling, the *stronger* the oscillation required for inducing a given grid potential. The oscillation thus increases with decreasing coupling coefficient, until the plate current varies over the entire portion of the characteristic curve of the valve. A further decrease in coupling can no longer support more plate current and eventually the power will begin to

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\* a *closed* oscillator is one that has its frequency determining components onboard - that is , it does not depend on external loading or tuning components to function.



drop off until oscillation finally ceases all together. On the other hand if the coupling in both networks is made tighter and tighter, eventually the plate current reduces to a level that the oscillations will also cease. So it is apparent that there is an optimal amount of coupling that is very important in achieving stable high power output. When we take power from the oscillator, we must replace it. (19)

As described before, some grid bias naturally occurs with the high filament voltage but there is a problem with the circuit in that the grid is not completely cut off because there is no grid leak or fixed bias and this causes over dissipation and the possibility of the oscillator not starting properly. So the modern versions from 1914 on, all show grid (gate, base) bias control.(20)

"A frequent bone of contention in radio patent litigation is the grid leak. (See Patents, U.S. 1,282,439, Br. 147,148 to Langmuir; and U.S. 1,377,405 to De Forest.) In a somewhat lesser degree, questions arise regarding the "C" battery or the application of a steady voltage to the grid of a triode. (See

Patents, Br. 1,482/11; U.S. 1,038,910 to Von Lieben et al; U.S. 1,231,764 to Lowenstein; U.S. 1,282,439 and Br. 147,148 to Langmuir; Br. 13,248/14 to Round; and U.S. 1,426,754 to Mathes.)" (21)

The Meissner oscillator is an example of how a non-linear device (the Lieben valve) can produce a sine-wave output that is not distorted. Although class C operation is nonlinear and many harmonic frequencies are generated, only one frequency receives enough gain to cause the circuit to oscillate. This is the frequency of the resonant tank circuit. Thus, high efficiency and an undistorted output signal can be obtained.

## HETERODYNE RECEIVER

The newer (new in 1910) continuous wave transmissions coming from undamped sources such as alternators had no tonal quality that a crystal detector could demodulate. Vacuum tube oscillators would have a similar continuous signal nature. Several clever ways of post detection *re-modulation* were developed using a *ticker* or slipping contact detector, a motor driven rotating car-

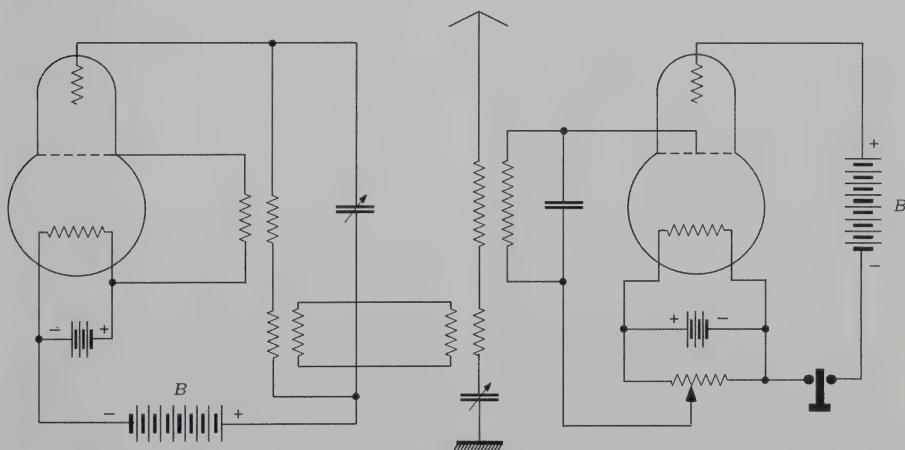


Fig. 12. Heterodyne Reception (Using 1911 Detector and 1913 Oscillator)

pacitor and finally a tone wheel. A more sensitive and pleasantly stable CW demodulation system was the beat receiver or heterodyne method. The original heterodyne technique was pioneered by Canadian inventor-engineer, Reginald Fessenden. Fessenden made his discovery in 1902, before the vacuum tube oscillator.(4) He was forced to use an alternator or a somewhat unstable "singing arc" as his BFO, so the clever technique was limited to very low frequencies. Recalling this and in Meissner's own words in a translated address from 1953, (22) he talks about the discoveries of 1912 in regard to the "Machine Transmitters" that were also called alternators. These devices were limited in frequency but produced almost perfect CW tone. (The text is in German but I have attempted a translation ... *Author*)

"During spark reception with a simple detector, the tone of the radio characters is clearly perceptible in a headphone; but everything remains quiet with the receipt of an undamped continuous wave telegraphy transmitter with a detector. Only at the beginning and end of each Morse signal one hears a quiet cracking. One improvement is a way that scrambles the DC developed in the detector with the receipt of a transmitter by a circuit breaker thus producing an alternating current audible in the headphone. But when atmospheric disturbances occur, it is nearly impossible to hear the characters. The machine transmitter was finished, but we had however no acceptable reception procedure for satisfactory reception of continuous wave. In the excitement we found a yellowed, forgotten patent of R.A. Fessenden from the year 1905. (23) Interference tones should be produced

with a telephone, which consisted of two closely aligned generator decks. Through the one the receipt stream went through the other the frequency somewhat deviating auxiliary generator. The mechanical reciprocal effect between the coils fastened on diaphragms produced an interference tone.

For us it was an illumination at that time, when we came on the thought to make the interference procedure technically useful by it that we mixed the two oscillations in an electric circuit and rectified them with a detector. So we had the interference tones in a normal telephone. But our local generator existed in a large 10-KW machine in more than 50 m distance of the receiver. The interference tones were for us like magic, particularly when atmospheric disturbances occurred. But they varied with the number of revolutions of the machine. We had to find a new technical solution at this point. We found it: the heterodyne, the Lieben valve with feedback, the small tube generator arbitrarily adjustable in the frequency. It was added to each receiver. Interference free reception was now the norm. Thus at that time the tube transmitter in its first implementation saved the machine transmitter. Later the machine transmitter was displaced by the tube transmitter as it developed both in power and sophistication."

In this description Meissner describes a beat frequency alternator station of 10 kW located near the main transmitter which, could actually service remote receivers! This certainly is an innovative beat frequency oscillator (BFO) service approach. He goes on to describe how difficult it was to get the beat oscillators stable enough for useful heterodyne re-

ception before the valve oscillator's existence.

At Telefunken, in 1912 it made a lot of sense to experiment with the Lieben valve as a possible high frequency BFO. After the oscillator Patent in 1913, Meissner used the oscillator to produce stable heterodyne reception and filed major Lieben valve circuit patents in 1914. Many heterodyne reception demonstrations followed. (24)

This schematic (Fig. 12) is a composite of two published schematics that I have sewed together. I have no original showing how Meissner actually connected the two circuits. He may well have used a crystal set rather than a Leiben plate detector but this connection makes the most logical sense to me, since it leverages the valve technology to the greatest effect for Telefunken. A modern version of this circuit might use a 12AU7 and of course would include grid bias. Better yet we would inject the BFO energy in a

place so as not to cause re-radiation as with a multigrid tube or even utilize a balanced mixer topology. Meissner focuses on this subject in later patents.

## REGENERATIVE DETECTOR

One must admit that Meissner's Regenerative Detector Patent DRP 290257 of 16 December 1913 shows a very nice schematic of a regenerative receiver. (26) Again there is nothing incorrect, odd or hard to understand about this circuit diagram (Fig. 13). It is the prototype of the modern regenerative circuit, complete with tickler in the plate circuit, throttle condenser and audio output transformer. The four-coil approach would provide excellent performance on a modern regenerative design. The valve receiver aided by retroaction increases gain and selectivity by hundreds over the crystal detector or even surpasses the crystal detector aided by

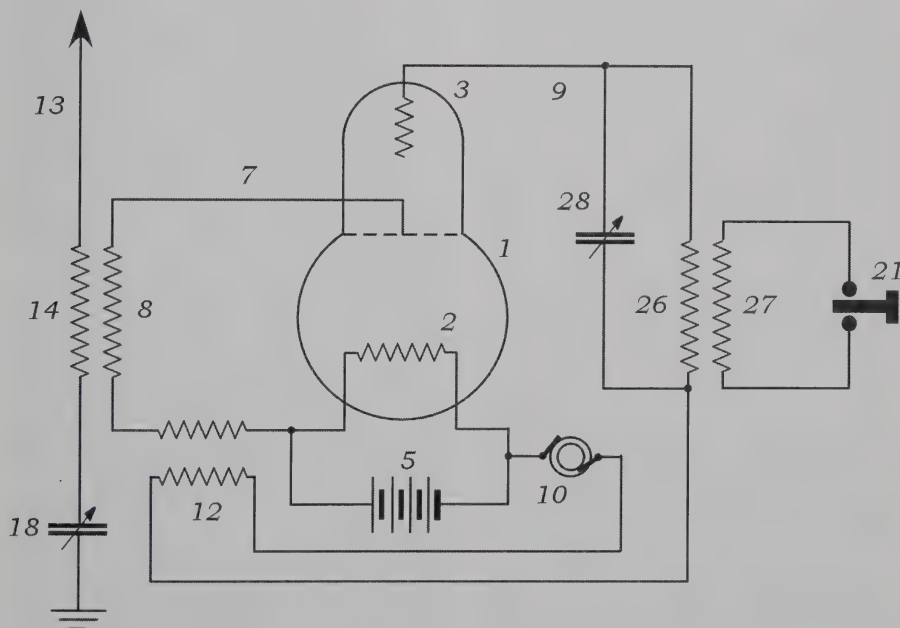


Fig. 13. Meissner Regenerative Receiver of 1913



a simple one-step audio or RF stage. Take a careful look at the DeForrest and Armstrong patent diagrams compared to this one. (27,28) Because the Audion oscillates so readily, they no doubt both functioned as drawn, but they sure do make you scratch your head compared to the clarity of this circuit!

## THE TECHNICAL BATTLE ENDS

Soon after 1914, all of the inductive feedback circuits from most of the major manufacturers pretty much start to look the same. The technical battle has ended for this oscillator and manufacturing begins on all kinds of radio gear just in time for World War I. The legal battle over these circuits is already in full swing! Ultimately four parties seem to have a major claim to regeneration. But again, Meissner's claim being one of the strongest is simply thrown out due to the onset of hostilities of World War I.

"The patent situation as regards to retroaction is interesting. The first patent embodying retroaction applied for in Great Britain was that of Telefunken Company due to Meissner. This was shortly followed by application for a similar patent by the Marconi Company and Franklin, the only difference being that magnetic coupling was used in the first application and direct coupling in the later. Should the Telefunken-Marconi agreement to exchange patents, now that the war is ended, again become effective, this complication would have little effect, but otherwise the situation offers great legal possibilities. (7)

## CONCLUSION

Most of the early circuits from 1914 on use a form of feedback,

which Americans simply call *Armstrong* and Europeans call *Meissner*. That is, a grid coil and a plate coil in magnetic coupling for positive feedback, with either one or both tuned in association with an active device. In fact we now know that in 1912 several people (companies) were simultaneously developing this form of oscillator using various valve technologies at their disposal. Add to this that the developments were coming so fast that it is hard to tell who exactly the father of the circuit was.

If the Meissner Oscillator looks a lot like an Armstrong Oscillator, that is because the final evolution of each has turned out to be identical. In other words a tuned (Grid, Plate, Gate, Drain, Base, Collector) *Armstrong* is the same as a tuned (Grid, Plate, Gate, Drain, Base, Collector) *Meissner*. In Europe the Meissner name prevails and in the USA, the Armstrong name prevails. As a minor point of difference, some texts call the tuned grid version the Armstrong and the tuned plate version the Meissner.

But the clarity and exactness of the Meissner schematics speak volumes. These reveal a professional engineer; a scientist who understood the potential of several critical radio technologies seemingly all at once. He produced at least 3 concise working radio circuits based on the feedback invention, which could immediately be put into production. My intent was not one of malice; it was to simply introduce you to another important contributor with which you may not be familiar. Nothing changes of course. We still have our opinions on who the "Father of Regeneration" might be. But now that we have *Regenerated* Meissner, we may once again

be forced to dig deeper.

## APPENDIX 1 SELECTED QUOTED SOURCES:

"C.S. Franklin, returning from a visit to Germany with samples of the Leiben-Reisz valve, brought back the news that Alexander Meissner of Telefunken had claimed to have found a way of making this type of valve act as a generator of continuous-wave oscillations. This information was at once exciting and alarming because both Franklin and Round were on the threshold of similar discoveries. Unknown to any of them, Armstrong in the United States was working on parallel lines. In the event, Meissner won the race, taking out a patent on 9 April 1913. C.S. Franklin's Patent was registered in June; Armstrong's in October and H.J.Round's in May 1914." (6)

"This situation needs some qualification however. Without wishing to detract from Meissner's brilliance as an engineer, it is on record that the apparatus he used was very inefficient. The Wehnelt cathode used in the Leiben-Reisz valve lasted only a few minutes in the circuit and the power output was very small. Round, although legally almost a year behind Meissner in terms of a patent, had in fact given a demonstration of valved radiotelephony between Marconi House and the Strand and Savoy Hotel in 1913. The Circuit he used was much more efficient and embodied an important innovation, notably that of a grid capacitor with a high resistance across it (a grid leak) and of a resistance in the anode circuit to limit the current flowing through the valve (negative feedback), thereby preserving it from the effects of excessive ionization." (6)

"In 1913 he was the first to amplify high-frequency radio signals by using a regenerative (positive) feedback in a vacuum triode; this principle made it possible to build radio receivers more sensitive than any earlier type. In June 1913 Meissner used this electronic circuit to transmit speech." (9)

"To Meissner must also be paid the credit of realizing in 1913 the possibility of using the 3-electrode thermionic valve for transmission, a result of which was closely followed by Armstrong in the United States in a few months." (7)

"In 1913, by the use of the Lieben tube, Meissner of Telefunken Company (Germany) succeeded in the oscillation of wavelength of 600 m, output power of 12W, and consequently carried out the wireless telephony with a distance of 36 km. This is known as the first utilization of continuous oscillation by a triode in wireless telephony." (29)

Juni 1913: Wechselseitiger drahtloser Sprechverkehr zwischen Nauen und Berlin (37 km) mit Meißners Röhrensender (mit Lieben-Röhre). Damit begann die "Ära des Röhrensenders". Marconi erkannte Meißners Priorität an: Meissner "employed the oscillating valve for the first time as carrier-wave generator for transmitting speech".(30)

"There was an engineer who had applied for a patent on the regeneration circuit prior to Armstrong. He was the German engineer Alexander Meissner, who filed a US patent on a regenerative circuit in March 1913. Langmuir, a well-known scientist-engineer at GE, applied for a patent on 29 October 1913, the same day when Armstrong filed his patent. De Forest applied for a patent on the ultra-audion (a re-

generation circuit) in 1914, but his patent was not accepted by the Patent Office, because of Armstrong's previous patent. Therefore, de Forest and others filed an "interference proceeding" to the Patent Office, and a proceeding for the four parties involved – Armstrong, de Forest, Meissner, Langmuir – began". (31)

"The Year Book for 1923, which is published by a Marconi subsidiary in London, credits the invention of the self-heterodyne to Meissner of Berlin 1913, whereas it was specifically patented to H.J. Round in Britain by Patent No. 28,413 of that year, and Meissner expressly disclaims it. (Br. Pat. 252/14.) Nevertheless – and despite the further disclaimer of the British patented inventions of Franklin (13,636/13) and Armstrong (24,231/14) – Meissner's specification carries claims which appear to cover all three. If the reader is fond of mental exercise he will enjoy studying the latter (amended) specification in the light of the others mentioned therein... Whether or not the U.S. Patent Office differentiates or will differentiate, between the use of the "feed-back" circuit for the (a) generation of oscillations for transmitting purposes, (b) generation of oscillations for "heterodyne" reception, and (c) amplifying received signals, the author does not know." (21)

"The first to use the triode in a transmitter appear to have been Round in England, and von Arco and Meissner in Germany; but such use does not appear to have been specifically patented anywhere, unless, perhaps, in the latter country." (21)

"The use of a triode valve as the generator of oscillations was not appreciated until 1912, again by

Meissner, then employed by the Telefunken Company, who arranged an inductive coupling between the grid and anode electrodes and so achieved CW oscillation at a frequency determined by the anode-grid coupling circuit. At first the use of the oscillator was confined to low power applications, again using a "soft – valve", resulting from the inadequate evacuation of the glass bulb, which left residual gasses effecting its operation." (32)

"The first reference in the records of the British Patent Office to the use of a triode as a useful generator for transmission purposes, seems to be in the specification of Br. Pat. 252/14 \* to Von Arco and Meissner."

\* BR. PAT. NO. 252. Date of Application, January 5, 1914, Accepted, August 19, 1915, Improvements in and relating to Relay Arrangements for Alternating Currents (19)

"Our national record in wireless telegraphy, apart from the financial side is a sorry one. None of the new ideas that revolutionized the subject during the past seven years can be regarded as having their origin or full development in this country. The conception of beat reception is American. The three electrode thermionic relay is American. The method of generating oscillations by aid of the thermionic relay was invented (probably independently) in Germany and the United States. The control of high-frequency currents by magnetic relays is likewise of German and American origin. The multiplication of frequency by aid of the properties of iron is French, Italian and German." *Electrician*, Editorial, p228, 21<sup>st</sup> February, 1919. (7)

And of course the famous:



"In August (6 Aug 1912), he (deForest) connected the output circuit of one audion to its own input circuit, and according to his own description, he obtained regeneration or feedback amplification, as well as sustained oscillation. From Lee de Forest's entry in his notebook, April 22, 1912 & August 6, 1912, *ibid.*" (31)

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- ii. Manfred Thumm , Historical German Contributions to Physics and Applications of Electromagnetic Oscillations and Waves, Forschungszentrum Karlsruhe, Association EURATOM-FZK, Institut für Hochleistungsimpuls- und Mikrowellentechnik Postfach 3640, D-76021 Karlsruhe, Germany and Universität Karlsruhe, Institut für Höchstfrequenztechnik und Elektronik, Kaiserstraße 12, D-76128 Karlsruhe, Germany  
Phone: ++49 7247 82 2440, Fax: ++49 7247 82 4874, E-mail: [manfred.thumm@ihm.fzk.de](mailto:manfred.thumm@ihm.fzk.de)
- iii. German Patent Office <http://www.dpma.de/>

This article was peer reviewed.

## ABOUT THE AUTHOR

**Michael Murphy, WU2D**, has been playing with radio circuits since he was in middle school in the early 1970's. An amateur radio license soon followed and over one high school summer vacation period, he built just about every basic circuit he could get his hands on including all of the basic oscillator types, regenerative receivers and other radio circuits.

This was a transitional time in electronics and the switch from vacuum tube to solid state was underway and Mike learned both hand in hand. He obtained two engineering degrees in 5 years of college in the State University of New York system and Rochester Institute of Technology, with co-op experience. Graduating in 1980, his first job was in the special products engineering group at Motorola. This group catered to the undercover police customers and to the three letter agencies. This basically steered him into the police and military gear design business, working for a number of companies. He has designed a lot of body worn gear, both audio and video devices and plenty of disguised devices. He is presently pursuing a Masters in Systems Engineering at Stevens Institute of Technology.

Over the years Mike has written for *QST*, *Electric Radio*, and lately for the *AWA Journal*. "I was once challenged to come up with a crystal controlled regenerative receiver. Chuck Kitchin and I collaborated on that one and we published it in *QST* in 1997. My most popular article was done last year. It was *Secrets of the Dead Command Sets* in *Electric Radio*. I must have received a hundred e-mails and letters – everybody loves those things".

Mike was drawn in to the AWA four years ago by the Bruce Kelly Memorial 1929 QSO Party and he went nuts building up the gear and perfecting antennas for that contest. He finally won it last year along with the Linc!



Michael J. Murphy







